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THE MERGER OF TOP UNIVERSITY- EXPLORING THE OPERATIONAL EFFICIENCY OF TAIWAN'S NYCU FROM A FINANCIAL PERSPECTIVE

Chiou Rung Chen

Department of Educational Management, National Taipei University of Education, Taiwan

ccr0720@gmail.com

Abstract

This study utilized data envelopment analysis (DEA) to empirically evaluate the operational efficiency of Taiwan's top university NYCU from a self-financing perspective between 2012 and 2023. The results demonstrated that although the merged NYCU maintained increasing returns to scale (IRS) in research output, his teaching output transitioned to more severe decreasing returns to scale (DRS) beginning from the second year post-merger (2022). This shift, coupled with a simultaneous surge in four input factors—particularly administrative and general affairs expenses—drove NYCU's overall operations into increasingly severe scale inefficiency. The findings confirmed that the merger-induced diversity of fields, disciplines, and missions, along with the multi-campus structure, resulted in diseconomies of scale and scope. Additionally, the study identified NYCU's strong resilience against declining birthrate impacts, while noting that

Taiwan's current public university tuition system undermined institutional financial stability and efficiency.

Keywords:

Top University, Merger, Data Envelopment Analysis (DEA), Technical Efficiency, Pure Technical, Efficiency, Scale Efficiency, Economy of Scale, Economy of Scope

1. Introduction

Compared with ordinary universities, top universities usually had more and higher-quality resources in a country or even the world, such as funds, talents, hardware and software equipment from the governments and enterprises. Therefore, top universities were often given higher expectations for talent cultivation, technology upgrading, and even national competitiveness enhancement (Salmi, 2009; Lo and Hou, 2020; Agasisti et al., 2021; Chen, 2024b). Especially in this era of rapid technological progress and the growing importance of universities' responsibility for the sustainable development of society. However, possessing abundant and high-quality resources did not guarantee the achievement of expected outcomes. Effective management and utilization were also required in order to maximally ensure the attainment of anticipated goals. Therefore, the long-term tracking of financial performance and production efficiency in top universities was both critically important and necessary for the optimization of a nation's higher education policy (Liu et al., 2019; Ripoll-Soler & de-Miguel-Molina, 2019; Chen, 2020b, 2024a, 2024b). However, most studies have historically focused solely on the research performance of top universities, neglecting their financial efficiency.

Among Taiwan's top universities, National Chiao Tung University (NCTU) collaborated with TSMC as early as 2013 to establish the "NCTU-TSMC Joint Research Center." In 2015, NCTU further founded the world's first international college specifically oriented towards the semiconductor industry – the International College of Semiconductor Technology (ICST). In 2020, NCTU partnered with TSMC again to launch the Semiconductor Program, aiming to encourage more students to pursue careers in the semiconductor industry, thereby establishing a sustainable talent pipeline and enhancing both the caliber and size of the semiconductor talent pool.

Furthermore, in February 2021, NCTU officially merged with National Yang-Ming University (NYMU) to form National Yang Ming Chiao Tung University (NYCU), marking the second case of a merger involving top universities in Taiwan's history. However, due to the relatively short time since the merger, research specifically concerning the newly formed NYCU is currently very scarce. There was an even greater lack of studies investigating changes in his operational efficiency before and after the merger.

In addition, Chen (2024b) conducted a financial ratio analysis from the perspective of financial performance on two top universities in Taiwan that have completed mergers. The study

found that the two top universities, NYCU and NTHU, exhibited issues such as poor cost control, inefficient asset utilization, and poor financial robustness. Furthermore, the research discovered that the financial performance of the post-merger top universities not only failed to improve but even showed a downward trend. Notably, while NCTU's asset utilization efficiency had consistently been higher than NYMU's before the merger, it decayed after the merger. This finding prompted the present study to further adopt an efficiency analysis methodology to verify the operational efficiency of the top university NYCU.

In summary, this study purposed to employ data envelopment analysis (DEA) to investigate the top university NYCU's operational efficiency between 2012 and 2023. The findings of this research were expected to provide valuable references for policymakers and university administrators to optimize resource allocation and enhance the competitiveness of both the university and the nation. Additionally, the research endeavored to enhance understanding of NYCU among governments, corporations, universities, and citizens worldwide. Ultimately, so as to foster increased international exchange and collaboration, thereby advancing global higher education institutions (HEIs)' implementation of sustainable development goals (SDGs) for the betterment of human society.

Section II contained literature reviews. Section III illustrated the methodology employed in this study. Section IV manifests empirical results. Section V concluded the results, along with made some suggestions.

2. Literature Review

Since the late 1990s, driven by financial pressures on higher education institutions due to declining birthrates and fiscal austerity, as well as global trends such as rapid technological advancement and globalization, many countries launched initiatives to establish so-called "world-class universities" or "top-tier universities", aiming to enhance national competitiveness by highly concentrating national resources to strengthen talent cultivation and research capabilities. (Lo & Hou, 2020; Oleksiyenko et al., 2021).

Decades have passed, yet there was a scarcity of academic research on top universities. The limited existing studies primarily focus on their international rankings, with some even concentrating solely on their research performance (Liu et al., 2018; Agasisti et al., 2021). However, as highlighted by Papadimitriou & Johnes (2019) and Chen (2020a, 2020b, 2024a),

HEIs must possess excellent management capabilities, particularly in financial management, to ensure resources allocation efficiency and financial stability. This was essential for maintaining the quality of teaching and research, thereby securing sustainable development and the fulfillment of university social responsibilities. Moreover, Bonaccorsi et al. (2022) and Chen (2024b) also emphasized the necessity and importance of using financial metrics for evaluating HEIs' efficiency, though the former was unable to adopt this approach due to the lack of cost data for most European universities.

On the other hand, driven by considerations such as declining birth rates, fiscal austerity, efficiency, and competitiveness, HEIs' mergers had also become a common trend across in many countries. However, so far, research findings on the impact of mergers on HEIs' performance and their underlying causes remained highly divergent. Papadimitriou & Johnes (2019) and Chen (2020a, 2020b, 2024a) demonstrated that HEIs with excellent management, teaching and research capabilities could be most likely to enhance or maintain post-merger HEIs' efficiency. However, Papadimitriou & Johnes (2019), Johnes & Tsionas (2019), and Chen (2020b, 2024a) found that the post-merger HEIs exhibited efficiency only in the first year.

Johnes & Johnes (2016), Wolszczak-Derlacz (2018) revealed that mergers brought economies of scale to HEIs. Furthermore, Kyvik & Stensaker (2013), Johnes & Johnes (2016), Wolszczak-Derlacz (2017), Wolszczak-Derlacz (2018), Ripoll-Soler & de-Miguel-Molina (2019) revealed the diversity in fields and disciplines may enhanced efficiency, implying the effect of scope economy after a merger.

Although Johnes & Johnes (2016), Wolszczak-Derlacz (2017), Wolszczak-Derlacz (2018), and Ripoll-Soler & de-Miguel-Molina (2019) pointed out that mergers brought both economies of scale and scope to HEIs, Papadimitriou & Johnes (2019) and Bonaccorsi et al. (2022) found that scale negatively impacted research efficiency, implying that mergers may result in diseconomies of scale. Since Papadimitriou & Johnes (2019) also found that efficiency improved after mergers, they inferred that mergers may enhance the efficiency through economies of scope rather than economies of scale.

However, Olivares & Wetzel (2011) found serious diseconomies of scope in cross-disciplinary teaching among small and medium-sized HEIs of applied sciences in Germany. Furthermore, Chen (2020a, 2020b), Slade et al. (2022), and Chen (2024a) revealed that the merged HEIs with well diversification across fields and disciplines simultaneously experienced

both diseconomies of scale and scope. Also, nonlinear effect were found in some studies. Daraio et al. (2015) found inverse u-shape effect of the disciplines diversity on efficiency, showing the nonlinear effect of scope economy. Similarly, Johnes & Tsionas (2019) showed that the nonlinear effect of size on post-merger HEIs' inefficiency, indicating the nonlinear effect of scale economy.

On the other hand, Koshal & Koshal (1999), Duch Brown et al. (2010), Johnes (2014), Frølich & Stensaker (2021) revealed the scope economy effect arising from mission diversity and implied that the higher the diversity of missions both in terms of outputs produced (research, teaching or third mission) and/or in terms of subject mix, the higher the efficiency.

Nevertheless, Olivares & Wetzel (2011) found strong diseconomies of scope between teaching and research in small and medium-sized universities of applied sciences in Germany. Slade et al. (2022) found that mergers between research-oriented and teaching-oriented universities led to a decline in research output, indicating that mission diversity resulted in both scale and scope diseconomies in research output for merged universities. Bonaccorsi et al. (2022) found diseconomies of scope between teaching and research in the field of medicine among European universities, when the research output was measured in terms of excellent production of research (count of publications or citations from the top 10% or 25% journals in the distribution of SNIP (source normalized impact per paper) in the GRBS dataset).

Daraio et al. (2015), Puusa & Kekäle (2015), Wolszczak-Derlacz (2018), Safavi & Håkanson (2018), Russell (2019), Wollscheid & Røsdal (2021), Ursin & Aittola (2021), and Slade et al. (2022) found that post-merger HEIs may experience increased complexity and costs due to misalignments in organizational expansion, multi-campus structures, academic identity, cultural identity, and affective commitment. As a result, merged HEIs may face situations where negative effects outweigh positive ones, implying possible diseconomies of scale and scope caused by decreasing returns to scale.

In summary, despite numerous studies on the impact of university mergers, which covered many countries and different time periods, the results remained highly inconsistent. Furthermore, there was very little research specifically on the mergers of top universities, and studies on such mergers from the perspective of financial efficiency were even rarer. This was what led to the present case study, which combined DEA and financial metrics to evaluate the operational efficiency of a merger involving a top university.

3. Research Design and Methodology

3.1 Methodology

Building on prior research that highlighted the need for flexible methodologies to account for inefficiency and avoid model misspecification bias (Andrews et al., 2002), this study adopted the nonparametric DEA method to evaluate the relative operational efficiency of top university NYCU in Taiwan from 2012 to 2023. Twelve years of efficiency tracking, spanning pre- and post-merger periods, to provide a clearer understanding of NYCU's operational efficiency and the factors influencing it.

DEA is a nonparametric method that does not presuppose a functional form, originating from Farrell's (1957) efficiency measurement framework. The technique uses linear programming to construct an efficiency frontier from all sample units, then evaluates each producer's relative efficiency by comparing their production points against this frontier. Charnes et al. (1978) formalized DEA under input orientation and constant returns to scale (CRS), establishing the CCR model. Banker et al. (1984) later extended this framework by relaxing the CRS assumption, enabling estimation under variable returns to scale (VRS) – known as the BCC model. Joint application of CCR and BCC models allows DEA to distinguish whether technical inefficiency stems primarily from pure technical inefficiency (suboptimal resource utilization) or scale inefficiency (failure to achieve cost-minimizing production scale). The CCR and BCC models are further stated as follows, respectively.

3.1.1 CCR Model

Charnes et al. (1978) extended Farrell's (1957) efficiency framework to multi-input/multi-output production contexts using linear programming and assuming CRS state of production. The model inherently excluded scale-related inefficiencies. The CCR was formulated as follows:

$$\text{Min } \alpha_j \tag{1}$$

$$s.t.\ Y^{Overall}\rho > Y_j \tag{2}$$

$$X^{Overall}\rho \leq \alpha_j X_j \tag{3}$$

$$\rho \geq 0 \tag{4}$$

where, α_j: the percentage of cuts the jth HEI needs to make in order to be efficient, ρ: N × 1 vector of each HEI's weight forming efficient frontier, $Y^{Overall}$: Q × N matrix of Q types of outputs for overall HEIs, $X^{Overall}$: R × N matrix of R types of inputs for overall HEIs, Y_j: Q × 1 matrix of Q types of outputs for the jth HEI, X_j: R × 1 matrix of R types of inputs for the jth HEI, α_j is the efficiency score for the jth HEI and a value of 1 indicates that the HEI is technically efficient.

3.1.2. BCC Model

Banker et al. (1984) further extended the framework by considering potential scale diseconomies to generate the so-called BCC model. This relaxation of the CRS assumption enabled efficiency measurement under variable returns to scale (VRS), comprising increasing return to scale (IRS) and decreasing return to scale (DRS). The BCC model was formulated as the follows:

$$\text{Min } \alpha_j \tag{5}$$

$$s.t.\ Y^{Overall}\rho > Y_j \tag{6}$$

$$X^{Overall}\rho \leq \alpha_j X_j \tag{7}$$

$$N'\rho = 1 \tag{8}$$

$$\rho \geq 0 \tag{9}$$

where, α_j: the percentage of cuts the jth HEI needs to make in order to be efficient, ρ: N × 1 vector of each HEI's weight forming efficient frontier, $Y^{Overall}$: Q × N matrix of Q types of outputs for overall HEIs, $X^{Overall}$: R × N matrix of R types of inputs for overall HEIs, Y_j: Q × 1 matrix of Q types of outputs for the jth HEI, X_j: R × 1 matrix of R types of inputs for the jth HEI, N: N × 1 vector of ones.

The linear programming estimation from CCR model can gain the technical efficiency (TE) scores and assess each HEI's overall operational efficiency relative to the sample-wide efficiency frontier. Conversely, the linear programming estimation from BCC model can gain the pure technical efficiency (PTE) scores which reflect efficiency independent of scale effect.

Banker et al. (1984) demonstrated that TE can be decomposed into PTE times scale efficiency (SE) as follows:

$$\mathrm{TE} = \mathrm{PTE} \times \mathrm{SE} \tag{10}$$

Therefore, SE could be gained by dividing TE score by PTE score,

$$\mathrm{SE} = \frac{TE}{PTE} \tag{11}$$

The efficiency scores of individual HEI was range from 0 to 1. Only when a HEI achieves both pure technical efficiency (i.e. PTE=1) and scale efficiency (i.e. SE=1) could he achieve technical efficiency (i.e. TE=1). Namely, a relative technical efficiency HEI (i.e. TE=1) manifested he possessed outstanding management, teaching and research capacities to well use his resources (i.e. PTE=1) as well as produced at the stage of optimal scale, i.e. CRS (i.e. SE=1).

Conversely, if a HEI was poor in management, teaching and research capabilities (i.e. pure technical inefficiency, PTE<1), or is not in an optimal production state (scale inefficiency, i.e. SE<1), he showed technical inefficiency (i.e. TE<1).

For a HEI exhibiting pure technical inefficiency (PTE<1), enhancing management practices and academic capabilities (teaching/research) was essential to optimize resource utilization and improve PTE. Consequently, in merger scenarios, the achievement of PTE by the consolidated entity was contingent on whether his management practices and academic capabilities were enough to optimize resource utilization after the merger.

On the other hand, a HEI exhibiting scale inefficiency (i.e. SE<1) meant the HEI had deviated from optimal scale (i.e. CRS) and is therefore unable to minimize LAC. There were two cases, the one is IRS, the other is DRS. the IRS production state meant the HEI's proportion increased in outputs was greater than that in inputs and brought in economies of scale, namely, LAC decreased with enlarging outputs. Otherwise, the DRS production state meant the HEI's proportion increased in outputs was lower than that in inputs and brought in diseconomies of scale, that was, LAC increased with enlarging outputs. As a result, for a scale inefficiency HEI caused by IRS, further expanding in outputs will improved his SE. Nevertheless, for a scale inefficiency HEI with DRS, expanding outputs will further lower his SE, he therefore should cut

his inputs while keeping outputs unchanged or strive to increase outputs at a rate greater than input growth, that is, to achieve the production state of IRS, in order to boost his SE. Besides, by reshaping the LAC curve (LACC)—for example, through mergers or altering the output mix—a HEI may shift the curve rightward. This extended the range of economies of scale, and even generated economies of scope, allowing the HEI to improve his SE.

The potential economies of scope (Baumol et al., 1982) – the cost advantages from diversified outputs – could ameliorate scale inefficiency in HEIs by expanding multiple outputs to leverage shared institutional resources, achieving lower production costs than separate entities generating the same outputs individually. Whether scale inefficiency in HEIs stemmed from IRS or DRS, diversifying outputs enabled the realization of economies of scope, thereby ameliorating scale inefficiency.

In the case of HEI mergers, compared with individual pre-merger HEIs, the post-merger HEI was usually accompanied by an expansion in scale and scope, so the new-generated LACC of the merged HEI will shift to the right. This implies the emergence of economies of scale and/or scope in the merged HEI could be able to improve SE. However, if the merger did not contribute to economies of scale and scope, that is, if the merger brought diseconomies of scale and/or scope, the merged HEI showed a decrease in SE.

The decomposition of TE in DEA enables this study to further examine the impact of HEIs' merger on the post-merger HEI. By employing pre- and post-merger PTE score and SE score comparisons to evaluate the impacts of merger on institutional capacities and production state, respectively.

Specifically, an elevated post-merger PTE score indicated that under the right-shifted LACC, the merged HEI achieved enhanced resource utilization efficiency through upgraded management, pedagogical, and research capacities. Similarly, an elevated post-merger SE score reflected improved proximity to optimal production scale—enabled by economies of scale and scope—within the new cost frontier.

3.2 Measurement of Inputs and Outputs

DEA enabled the evaluation of relative efficiency with multiple inputs and outputs. The validity of the results depended on the proper specification of inputs and outputs and the

selection of suitable samples to construct the efficiency frontier. Accordingly, this study's methodological settings were outlined below.

Since the primary focus of this study was top university NYCU and aimed to extend Chen's (2024b) in-depth investigation into their financial efficiency, this research incorporated both regulatory requirements and practical financial reporting information to align with purpose and operational realities. Consequently, this study measured inputs and outputs in accordance with Taiwan's "National University Endowment Fund Establishment Act" and actual financial statement data, selecting major input and output categories to align with practical operations and reduce estimation bias.

Four inputs were considered: Teaching and research expenses (TeachCost), Combined expenses from academia–industry cooperation and government research grants (ReschCost), Administration and general expenses (A&GCost), and Net fixed assets (NFA). NFA was measured as the total stock rather than annual increments, since HEIs relied on their full fixed assets for production rather than increments.

Two outputs were included, both reflecting self-raised income: Tuition/fee revenue (TeachRev) and combined income from academia–industry cooperation and government research grants (ReschRev). This specification allowed assessment of HEIs' financial autonomy and efficiency in generating income independently of government subsidies.

Overall, this specification of inputs and outputs provided a more intuitive financial perspective for examining universities' relative operational efficiency. It captured not only the quantitative effects but also the price effects embedded in financial performance.

In this framework, PTE = 1 indicated effective use of the four input factors to produce the two outputs, reflecting sound management and academic capacity. SE = 1 implied operation at the most efficient scale (CRS), minimizing LAC. SE < 1 implied operation at the state of IRS or DRS. Under CRS, the combined growth rate of the two outputs equals that of the three costs and NFA; under IRS, the combined growth rate of the two outputs exceeds that of the three costs and NFA; and under DRS, it fell short.

3.3 The Construction of Efficiency Frontier

Since this study aimed to explore the relative operational efficiency of NYCU, a top university in Taiwan, and to consider the potential impact of inter-HEI heterogeneity on resource

and output-input mix and avoid estimation bias (Chavas et al., 2012, Chen, 2020), this study only adopted public comprehensive universities in Taiwan as a sample to construct the efficiency frontier. Consequently, this study comprised 27 public comprehensive universities from 2012 to 2016, 26 public comprehensive universities from 2017 to 2020, and 25 public comprehensive universities from 2021 to 2023 as sample to estimate efficiency frontier yearly.

4. Empirical Results

4.1 The Top University in Taiwan: National Yang-Ming Chiao Tung University (NYCU)

This study focused on the analysis of the operating efficiency of the second top university in Taiwan to undergo a merger: National Yang-Ming Chiao Tung University (NYCU), from a financial perspective rather than solely evaluating his efficiency based on research performance. Specifically, self-generated funding from teaching and research were used as two outputs, while teaching and research expenses, administrative and general expenses, and net fixed assets served as the four inputs. Here so-called 'top universities' in this study were those has long been highly funded by 'Aim for the Top University Project' from 2005 to 2017, the "Whole-School Program of Sustained Progress and Rise of Universities in Taiwan (SPROUT) Project" from 2018 to 2022, and the second phase of the "Higher Education SPROUT Project (HESP)" from 2023 to 2027 in Taiwan.

NYCU was formed through the merger of the smaller NYMU and the larger NCTU on February 1, 2021. NYMU was a research-oriented university and originated from the National Yang-Ming College of Medicine, founded in 1975, and was upgraded to university status in 1994, becoming Taiwan's first university with a focus on medicine. Over time, while consolidating its strengths in medicine, NYMU expanded his focus to broader biomedical sciences.

NCTU was a research-oriented university and originally founded in 1896 in the suburbs of Shanghai, China, and was re-established in his current location in Hsinchu, Taiwan, in 1957. In his early years, NCTU concentrated on developing the electronics industry to support national economic growth and defense, gradually securing a long-term leading position in Taiwan in electronics, information and communications, management, and science and engineering. For decades, NCTU has also been the primary source of talent for Taiwan TSMC, the world's largest semiconductor foundry, as well as for Taiwan's broader semiconductor

industry chain. This is attributable to NCTU's collaboration with TSMC as early as 2013, when the "NCTU-TSMC Joint Research Center" was established.

In 2015, NCTU further founded the world's first international college dedicated specifically to the semiconductor industry—the International College of Semiconductor Technology (ICST). In 2020, NCTU once again partnered with TSMC to launch the Semiconductor Program, aiming to encourage more students to enter the semiconductor industry, build a sustainable talent pipeline, and strengthen both the scale and quality of the semiconductor talent pool. Predictably, given the global shortage of semiconductor talent in recent years, the post-merger NYCU will become a critically important base for advanced semiconductor talent cultivation and research not only in Taiwan but also worldwide.

In addition to previous descript fields, in 2000 NCTU also set the goal of developing the biomedical field, including biomedical informatics, biomedical materials, biomedical electronics, and biomedical sciences, seeking to bridge telecommunications and biomedicine and position himself as a pioneer in Taiwan's biomedical technology industry. In recent years, NCTU has devoted himself to becoming a forward-looking R&D base for biomedical engineering in Taiwan, achieving a new milestone in its BioICT program in biomedical electrical engineering.

Given the distinct academic focuses of the two universities and the evolving needs of the era, both institutions expected that their merger would enable them to undertake major cross-disciplinary teaching and research missions, particularly in the fields of BioICT and Digital Bio-Medicine.

After the merger, as of 2023, NYCU had a total of 8 campuses spanning 5 counties and cities. His organization comprised 19 colleges and 1 affiliated hospital, with a total campus area of 858,831 square meters. The number of full-time faculty was 1,139, and the student population totaled 21,428. The merged NYCU experienced a substantial increase in his total project funding. Additionally, there was a significant improvement in his international rankings.

4.2 Efficiency Evaluation of NYCU

Table 4.1 showed the relative efficiency scores of NYCU estimated using DEA from 2012 to 2023. As shown in Table 4.1, NYCU maintained scores of 1.0 in technical efficiency, pure technical efficiency, and scale efficiency from 2012 to 2021, indicating that throughout this

period, the university consistently achieved relative technical efficiency compared to all public comprehensive universities in Taiwan. This stemmed from his excellent management, teaching and research capabilities (i.e., attainment of pure technical efficiency, PTE=1) while operating at optimal scale (i.e., achievement of scale efficiency, SE=1), enabling him to effectively utilize the four inputs (TeachCost, ReschCost, A&GCost, and NFA) to generate two major self-raised funds (TeachRev and ReschRev), while maintained a scale that minimizes LAC.

However, a shift occurred starting in 2022. Since 2022, although NYCU's PTE score remains at 1.0, his SE score declined to 0.989 in 2022 and further dropped to 0.961 in 2023. Consequently, his overall TE scores fell to 0.989 and 0.961 in 2022 and 2023, respectively.

This signified that since 2022, despite retaining robust management, teaching and research capabilities, NYCU had experienced technical inefficiency due to operating at a scale of diseconomies—specifically, under decreasing returns to scale (DRS). Moreover, this inefficiency showed a trend of progressive deterioration year by year.

Table 4.1 *DEA efficiency scores of NYCU from 2012 to 2023*

		Public Comprehensive HEIs Efficiency Frontier												
NCTU	**Efficiency**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Mean**
	TE	1	1	1	1	1	1	1	1	1				1
	PTE	1	1	1	1	1	1	1	1	1				1
	SE	1	1	1	1	1	1	1	1	1				1
	State	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS				
NYCU	**TE**										1	0.989	0.961	0.983
	PTE										1	1	1	1
	SE										1	0.989	0.961	0.983
	State										CRS	DRS	DRS	

4.3 Investigating NYCU's Shifting Efficiency

Since the DEA estimation results indicated that starting from the second year after the merger, NYCU gradually exhibited a trend of DRS in his overall output, revealing the combined growth rate of NYCU's two major outputs was lower than the combined growth rate of his three cost categories and net fixed assets, this study further investigates the reasons behind the emergence of DRS in the post-merger NYCU.

The reasons for the overall production exhibiting DRS in NYCU during 2022–2023 may include:

1. All output items showing DRS.

2. The DRS effect of one output outweighed the IRS effect of the other output. That was, the absolute value of distance of growth rate of outputs and inputs for DRS outputs is greater than that for IRS outputs.

3. Diseconomies of scope, meaning the total cost of joint production (post-merger) was greater than the total cost of separate production (pre-merger). This implied that LAC increases with expanding output, i.e. DRS, after the merger. In the case of NYCU, this may arise from diversity of fields, diversity of disciplines, and/or diversity of missions.

To further investigate the reasons behind the DRS in the post-merger NYCU—specifically, which output item was causing the DRS and whether the merger led to diseconomies of scope—this study designed the research based on the following considerations:

1. To prove which output experienced DRS and thus led to diseconomies of scale in overall production, it was necessary to calculate and compare the growth rates of the two outputs and the four inputs, respectively

2. To demonstrate diseconomies of scope from merger, it must be shown that at least one output exhibited DRS after the merger.

Based on the above, this study used the year immediately preceding the statutory year of merger, i.e., 2020, as the base year. The four inputs and two outputs of NCTU and NYMU in 2020 were summed separately to serve as proxy measures for the four inputs and two outputs of their independent production prior to the merger. The growth rates of these six variables—four inputs and two outputs—for NYCU from 2021 to 2023 were then calculated. This approach enabled an evaluation of which output(s), compared to the pre-merger period (i.e. 2020), exhibited lower growth rates than the input growth rates after the merger (i.e. the presence of DRS), indicating the presence of scale diseconomies. Furthermore, since the growth rates for 2021–2023 (representing joint production) were calculated relative to the aggregated 2020 values of the two universities (representing separate production), if an output showed DRS, it demonstrated that the presence of scope diseconomies for that output post-merger.

In summary, the analyses descripted above were summarized in Table 4.2, aiming to gain in-depth insights into: why did the NYCU's overall production state exhibit DRS post-

merger? That was, compared to the pre-merger period (i.e. 2020), which output(s) showed DRS and thus indicating economies of scale and scope?

Compared to the aggregate values of the two pre-merger universities (NCTU and NYMU) in 2020 (the year before the legal merger base year), NYCU demonstrated improved revenue and reduced costs in the first post-merger year (i.e. 2021). The two outputs, i.e. TeachRev and ReschRev, both increased, by 1.13% and 3.93%, respectively. Input factors including TeachCost and NFA both decreased, by 2.57% and 0.89%, respectively. Although ReschCost and A&GCost increased by 3.14% and 0.43%, respectively, NYCU maintained overall scale efficiency (SE = 1.0) in 2021. This was due to both teaching and research exhibiting increasing returns to scale (IRS)—specifically, the growth rate of TeachRev exceeded that of TeachCost, while the growth rate of ReschRev surpassed that of ReschCost. In addition, IRS in teaching and research demonstrated that the merger has brought economies of scale and scope to NYCU's teaching and research in the first year.

However, in the second post-merger year (i.e. 2022), while NYCU's ReschRev increased by 16.74% compared to the pre-merger baseline, TeachRev decreased by 6.05%. And critically, all input factors increased instead of decreasing. A&GCost saw the highest increase at 17.67%. ReschCost increased by 12.85%. NFA also increased by 0.99%. This combination resulted in NYCU beginning to exhibit scale inefficiency in 2022.

Notably, despite the decrease in TeachRev, TeachCost rose by 4.94%. The result showed that in the second year after the merger, NYCU’s teaching output had shifted from IRS to DRS. Moreover, the gap between the growth rates of teaching output and input widened, surging from 3.7% in 2021 (1.13% – (–2.57%)) to –10.99% (–6.05% – 4.94%). This indicated that, after the merger, NYCU experienced diseconomies of scale and scope in teaching output. In other words, although the merger led to diversification in fields and disciplines, the growth rate of teaching output still lagged far behind the growth rate of input, causing the LAC of teaching output to increase rather than decrease alongside such diversification.

When together considering the growth rate in student number in 2022, NYCU’s student number increased by 5.03% compared with the combined total of NCTU and NYMU in 2020, showing the top university's resilience against Taiwan’s declining birth rate. However, strict government regulation of tuition fees—especially for public universities—had severely constrained tuition revenue growth, creating a sharp mismatch with rising enrollment. Moreover,

TeachRev had grown at a slower pace than TeachCost, this further highlighted the infeasibility of the Ministry of Education's current tuition policy. The system not only failed to offset inflation but also undermined the goals of the Higher Education Sprout Project, which seeks to strengthen world-class universities. Consequently, NYCU faced challenges in sustaining optimal scale efficiency and long-run financial stability, thereby placing both his competitiveness and educational quality at risk.

On the other hand, in terms of research output, NYCU's growth rate of research output exceeded that of research inputs, indicating that in the second year after the merger, NYCU still maintained IRS in research output. Moreover, the disparity between the growth rates of research output and input widened. The expanding rate of IRS jumped from 0.79% in 2021 (3.93% – 3.14%) to 3.89% (16.74% – 12.85%). This result showed that NYCU, after the merger, experienced both economies of scale and scope in research output. In other words, the post-merger diversification across fields and disciplines indeed allowed NYCU's growth rate of research output to surpass that of input, thereby causing his LAC of research output to decline along with such diversification.

Furthermore, together considering both teaching and research outputs, although NYCU, after the merger, lived up to expectations by maintaining an IRS production state in research, he exhibited DRS in teaching output as early as the second post-merger year. Moreover, the IRS rate of research output (3.89%) was far lower than the DRS rate of teaching output (–10.99%). This result indicated that post-merger NYCU faced diseconomies of scope arising from diversity in missions; that is, faculty members encountered a trade-off between teaching and research and could not improve both simultaneously. Consequently, teaching and research could not both remain at an IRS production state. Additionally, the diseconomies of scope from diversity in missions had continued to worsen, as teaching output shifted from IRS in 2021 to DRS, while the IRS rate of research output expanded. This suggests that when faculty at top universities were faced with the trade-off between teaching and research, they tend to prioritize strengthening research at the expense of teaching. Over time, this tendency will be detrimental to national talent cultivation.

In the third post-merger year (i.e. 2023), although NYCU's TeachRev and ReschRev increased by 0.19% and 16.74%, respectively compared to the pre-merger baseline, all four input factors increased significantly. A&GCost had the highest increase at 24.78%. ReschCost

increased by 16.36%. TeachCost and NFA also increased by 5.6% and 1.72%, respectively. Ultimately, this substantial rise in inputs meant NYCU could no longer maintain his optimal production scale relative to the overall public comprehensive universities, resulting in relative scale inefficiency.

Similar to the situation in 2022, NYCU continued to exhibit DRS in teaching output in 2023. The growth rate of tuition revenue (0.19%) was far lower than that of instructional costs (5.6%). In addition, it was also much lower than the sharply rising student enrollment (8.68%). This once again highlighted that, although the top university NYCU possessed good resilience to the impact of declining birthrates, Taiwan's stringent price controls on university tuition—especially for public universities—caused the growth rate of tuition revenue to remain at only 0.19%, far below the growth rate of student enrollment and even lower than the growth rate of teaching costs. The findings further confirmed the infeasibility and irrationality of the current tuition policy of Taiwan's Ministry of Education.

On the other hand, the research output performance of NYCU in 2023 closely resembled that of 2022. His growth rate of research income exceeded that of research costs, indicating the presence of IRS in research output. Moreover, the gap between the growth rates of research output and input widened, that is, the IRS rate expanded. The expanding rate of IRS rose slightly from 0.79% in 2021 (3.93% – 3.14%) to 0.85% (17.21% – 16.36%), but was far lower than the 3.89% recorded in 2022. These results indicated that the economies of scale and scope brought by the merger to NYCU's research output had shown a declining trend.

Finally, together considering both teaching and research outputs, although NYCU in 2023 still maintained an IRS production state in research output, teaching output continued to remain in DRS. Moreover, the IRS rate of research output (0.85%) was far lower than the DRS rate of teaching output (0.19 – 5.6 = –5.41%). This result demonstrated that even three years after the merger, NYCU continued to experience diseconomies of scope stemming from diversity in missions. Faculty members still faced a trade-off between teaching and research and could not improve both simultaneously, resulting in a situation where teaching and research could not both remain at an IRS production state.

In fact, this study found that after the merger, NYCU's full-time faculty simultaneously faced an increased student–faculty ratio as well as a higher amount of project funding per faculty member. Compared to the pre-merger year of 2020, when the combined

student-faculty ratio of the two universities was 17, the student-faculty ratio of the merged NYCU increased to 18, 18, and 19 in 2021, 2022, and 2023, respectively. Meanwhile, the amount of project funding per faculty member was NT$4.56 million in 2020. After the merger, this figure at NYCU rose to NT$4.56 million, NT$5.16 million, and NT$4.97 million in 2021, 2022, and 2023, respectively. This indicated that both the burden of teaching and research per faculty member rose simultaneously, compared to the pre-merger period. Such a situation was unfavorable for the sustainable development of both the faculty and the university, whether from the perspective of faculty well-being or from the perspective of the quality of education and research.

Overall, after the merger, NYCU continued to maintain an IRS production state in research output, but in teaching output, he shifted to DRS as early as the second year. Moreover, the IRS rate of research output was far lower than the DRS rate of teaching output. The results attested NYCU experienced economies of scale and scope in research production (Ali & Gittelman, 2016, Johnes & Johnes, 2016, Papadimitriou & Johnes, 2019, Ripoll-Soler & de-Miguel-Molina, 2019, Chen, 2024a), though diseconomies of scale and scope in teaching production (Olivares & Wetzel, 2011; Daraio et al., 2015). In addition, the results indicating the presence of diseconomies of scope arising from diversity of missions in post-merger NYCU (Olivares & Wetzel, 2011; Bonaccorsi et al., 2022). Moreover, faculty members of NYCU tended to strengthen research and weaken teaching after the merger, which was consistent with Schimank & Winnes (2000), Daraio et al. (2015) and Lo & Hou (2020).

When combined with changes in student enrollment, it could be observed that in the first to third years following the merger, NYCU's student numbers increased by 3.53%, 5.03%, and 8.68%, respectively, compared to the total number of students at NCTU and NYMU in 2020. This demonstrated that while the post-merger NYCU had resilience against the declining birthrate, his tuition revenue growth lagged behind the growth rate of student enrollment—and even behind the growth rate of teaching costs—due to the unreasonable government tuition pricing policy.

In addition, this study found that the merger caused the top university NYCU a surge in the corresponding input factors, which grew rapidly year by year. The most affected item was A&GCost. In the first through third years after the merger, compared to the combined A&GCost of NCTU and NYMU in 2020, these expenses increased by 0.43%, 17.67%, and 24.78%,

respectively. Not only was this the input factor with the highest growth among the four inputs in the second and third post-merger years, but it also increased sharply year by year. This manifested that post-merger NYCU may have experienced increased complexity and costs arising from organizational expansion, multi-campus, incoordination in academic identity, cultural identity, affective commitment, and so on, leading to rising A&GCost—for example, greater difficulties in individual and organizational communication integration and/or exacerbation of bureaucratic inefficiencies rather than their improvement (Daraio et al., 2015; Puusa & Kekäle, 2015; Estermann & Pruvot, 2015; Zeeman & Benneworth, 2017; Wolszczak-Derlacz, 2018; Safavi & Håkanson, 2018; Russell, 2019; Wollscheid & Røsdal, 2021; Ursin & Aittola, 2021; Slade et al., 2022; Pritchard, 2022). Moreover, this finding also supports the existence of diseconomies of scale and/or scope for multi-campus operations at post-merger NYCU (Zeeman & Benneworth, 2017; Pritchard, 2022).

Finally, the results demonstrated that, overall, NYCU experienced diseconomies of scope arising from field diversity, disciplinary diversity, mission diversity, and a multi-campus structure. This is because, despite the merger increasing the number of fields and disciplines (as reflected in the expansion of his colleges and departments) and the number of campuses at NYCU, the overall growth rate of outputs after the merger remained lower than the overall growth rate of inputs compared to the two pre-merger institutions, i.e. at a DRS production state. In other words, as the number of fields, disciplines, missions and campuses increased, so did LAC.

Table 4.2: *Efficiency Component Analysis of NYCU*

unit: NT$ million, %, Person

Year	**2020**	**2020**	**2020**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**
University/ Variable	**NCTU**	**NYMU**	**NCTU +NYMU**	**NYCU**	**NYCU**	**NYCU**	**Yearly Growth Rate (%)**		
TeachRev	790	268	1058	1070	994	1060	1.13	-6.05	0.19
ReschRev	2688	927	3615	3757	4220	4237	3.93	16.74	17.21
TeachCost	3295	1564	4859	4734	5099	5131	-2.57	4.94	5.6
ReschCost	2670	924	3594	3707	4056	4182	3.14	12.85	16.36
A&GCost	262	202	464	466	546	579	0.43	17.67	24.78
NFA	9454	3466	12920	12805	13048	13142	-0.89	0.99	1.72

Number of students	15182	4534	19716	20412	20707	21428	3.53	5.03	8.68

Note: The annual growth rate of each variable from 2021 to 2023 is calculated based on 2020 as the base year.
Data source: Financial statements of NCTU, NYMU, NYCU.

5. Conclusion and Suggestion

This study utilized the DEA method to evaluate the operational efficiency of top university NYCU in Taiwan from a self-financing perspective between 2012 and 2023, namely, aiming to assess the top university's efficiency to use his four inputs to generate two main self-raised funds, and further traced why the scale efficiency decayed after the merger.

First, this study demonstrated that NYCU maintained pure technical efficiency during the period from 2012 to 2023. However, starting from the second year after the merger, in 2022, the university experienced scale inefficiency under a DRS production state, which resulted in overall technical inefficiency.

This study further found that although NYCU sustained an IRS production status in research output over the three years following the merger, his teaching output had already shifted to DRS as early as the second post-merger year, 2022. Moreover, the DRS rate of teaching output was far higher than the IRS rate of research output. Coupled with the sharp increase in the four input factors after the merger, especially the continued surge in A&GCost, this ultimately caused NYCU's overall production to exhibit scale inefficiency arising from the DRS production state since 2022.

This result attested that the merged top university, NYCU, had lived up to expectations by achieving economies of scale through IRS in research output, as well as economies of scope arising from field and disciplinary diversity, implying further expanding research output will lead to the minimization of LAC due to economies of scale and scope—such as diversity in fields, disciplines, and campuses—thereby improving scale efficiency and achieving the optimal scale with scale efficiency (SE = 1).

Furthermore, the results also manifested merged NYCU encountered both diseconomies of scale and scope arising from diversity in fields, disciplines, and multi-campus operations in his teaching output. Moreover, this study highlighted that NYCU's tuition revenue growth rate was greatly lower than his student number growth rate, indicating that the tuition

pricing restrictions imposed by the Taiwanese Ministry of Education on public universities were both unreasonable and unsustainable. Such a policy not only hindered the achievement of development goals for top universities but also adversely affects the educational quality and financial stability of NYCU.

Moreover, this result also confirmed that post-merger NYCU experienced diseconomies of scope due to mission diversification, indicating that his faculty encountered a trade-off between teaching and research, preventing both from simultaneously achieving IRS. This will be detrimental to faculty well-being as well as to the quality of teaching and research, thereby hindering the sustainable development of the top university NYCU. This result also showed that the Humboldtian-style university development model needed to be optimized.

Finally, merged NYCU seemed to experience increasing complexity and costs from organizational expansion, multi-campus, together with the incoordination in academic identity, cultural identity, affective commitment, and so on, leading to rising A&GCost.

In light of the above findings, this study offers the following suggestions to policymakers and NYCU. First, granting more pricing flexibility, particularly for top universities where the intensity and expenditures of teaching and research are higher. Second, optimizing the task allocation of top university faculty, since time and energy are limited, and even faculty at top universities find it difficult to enhance both teaching and research simultaneously. Third, strengthening post-merger communication and coordination to reduce unnecessary administration and general expenses. Fourth, considering how to enhance and leverage the economies of scope arising from post-merger diversification across fields, disciplines, and campuses, leading to achieve both scale and technical efficiencies. Finally, fully recognizing and considering optimizing policies based on the four suggestions above. Otherwise, even top universities with abundant resources and strong resilience to withstand the impact of declining birthrates may struggle to achieve economies of scale and scope through mergers, making his difficult to operate efficiently.

Looking ahead, this study remained highly optimistic about and anticipated significant teaching and research contributions from top-tier university NYCU, as it had indeed gathered exceptional faculty and students from across Taiwan and around the world, and had assembled substantial high-quality resources—particularly following the merger. Therefore, it is believed

that with continued efforts from both the government and NYCU, the top university will undoubtedly make advancing contributions to human society.

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