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BETTER SELF-FINANCING EFFICIENCIES OF TOP UNIVERSITIES? THE CASE OF NTU IN TAIWAN

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Abstract

Utilizing Data Envelopment Analysis (DEA) in conjunction with financial data analysis, this study assessed the self-financing efficiencies of the top university National Taiwan University (NTU) from 2012 to 2023. The results underscored the infeasibility of the current financial autonomy model for public universities in Taiwan, amidst the simultaneous and rapid exacerbation of the declining birth rate and the widening social wealth disparity. Furthermore, the findings signaled a precarious threat to the financial stability and long-term sustainability of public universities in Taiwan under the existing system. This suggested an urgent need for policy reforms to ensure the financial sustainability of universities and enable them to fulfill their social responsibilities.

Keywords:

Top University, Self-Financing Efficiencies, Financial Sustainability, Data Envelopment Analysis (DEA)

1. Introduction

The United Nations formally adopted the 2030 Agenda for Sustainable Development in 2015, which established the Sustainable Development Goals (SDGs), comprising 17 core goals and 169 specific targets. This agenda drove global emphasis on and implementation of sustainability, particularly within Higher Education (HE).

In response, many top universities in countries such as Singapore, South Korea, Japan, Canada and the United States, proactively published sustainability reports to maintain international competitiveness and align with global trends. These institutions typically followed international guidelines, such as the Global Reporting Initiative (GRI) Standards, to ensure their reports' transparency and credibility. In Europe, even without legal enforcement, many universities chose to voluntarily adhere to the standards of directives like the Corporate Sustainability Reporting Directive (CSRD), integrating sustainability reporting as an essential component of their daily operations and strategic planning.

Similarly, universities in Taiwan, encouraged by the Ministry of Education, actively fused the SDGs into their institutional development plans and subsequently published sustainability reports, thereby linking their operations to sustainability objectives, fulfilling their social responsibilities, and enhancing their overall impact.

Although sustainability and the practice of university social responsibility (USR) had garnered initial attention globally from nations and higher education institutions, the focus of top universities and the related academic literature were almost exclusively directed toward international rankings or research performance when evaluating their performance (Zhang et al., 2022). While university ranking systems provided a systematic methodology for assessing the performance of higher education institutions, the emphasis on sustainability within these existing frameworks remained relatively weak (Filho et al., 2024). Moreover, ranking systems and research focusing specifically on university financial sustainability were exceptionally scarce. For instance, major rankings such as the QS World University Rankings and the Academic Ranking of World Universities lacked any assessment of financial indicators.

However, amidst the global advocacy for USR and the Sustainable Development Goals (SDGs), coupled with the challenges of declining birthrates and fiscal austerity in many countries, this study contended that universities—particularly top universities which aggregated a greater quantity and higher quality of diverse resources—must ensure sound financial

management capabilities and efficiency. Specifically, the efficiency of converting inputs into self-financing revenue was deemed essential to guaranteeing the quality of education and research while simultaneously maintaining financial robustness. Only through such means could universities effectively fulfill their societal responsibilities in education, research, and community service, and simultaneously ensure their sustainability (Warren, 2023; Chen, 2024; Chen et al., 2024).

Moreover, recent literature by Stensaker and Hermansen (2025) indicated that even Nordic universities, which are traditionally characterized by values such as equity, justice, and inclusion and are thus expected to align strongly with the SDGs, exhibited significant divergence in their attitudes and practices toward these goals. Their analysis suggested that comprehensive universities, compared to their specialized counterparts, were more inclined to adopt a symbolic approach to the SDGs, lacking concrete implementation strategies. Notably, many of these institutions were top universities within their respective Nordic countries.

These findings prompted this study to investigate, from a financial perspective, whether top universities in Taiwan possess sound financial sustainability. Furthermore, by integrating an analysis of Taiwan's current regulatory framework, this research aimed to measure financial sustainability through the lens of self-financing efficiency and in-depth financial analysis. The ultimate objectives were to provide actionable recommendations for policy and institutional improvement, and to advocate for greater attention to university financial sustainability among international governments and higher education institutions.

The enactment of the Statute for the “Act Governing the Establishment of Endowment Fund at National Universities” in 1999 and its subsequent amendment in 2015 established the legal foundation for promoting financial autonomy in Taiwan's public universities. The spirit of Articles 11 and 13 of the statute allowed for the surplus from self-financing income to be retained within the university endowment fund for accumulation across fiscal years. This framework, integrated with the "Regulations for the Management and Supervision of National University Affiliated Endowment Funds" (promulgated in 1999, amended in 2021) and the "Uniform Accounting Standards for National University Affiliated Endowment Funds" (issued in 2018), collectively enabled public universities to allocate these surplus funds toward long-term development and strategic investments.

These allocations could be utilized for purposes such as enhancing faculty and staff remuneration, recruiting top talent, campus infrastructure development, and asset acquisition, all aimed at improving teaching and research performance. Furthermore, the funds could be directed into financial investments to ensure institutional financial efficiency and stability. Consequently, the efficiency in utilizing self-financing income was identified as a critical determinant of a university's financial sustainability and its ability to fulfill its social responsibilities.

Therefore, this study adopted a Data Envelopment Analysis (DEA) methodology to assess the self-financing efficiencies of top university, namely, the efficiencies in transferring four major input factors to two primary self-financing income (teaching and research).

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.

Among top universities in Taiwan, National Taiwan University (NTU) has consistently received the most substantial resources. For instance, NTU continuously secured the highest funding in Taiwan-wide initiatives, including the "Aim for the Top University Project" from 2006 to 2016, 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. Furthermore, NTU frequently ranked highest in corporate-sponsored research funding among public universities. Given this context, this study empirically investigated whether NTU utilized its abundant resources more efficiently to generate higher self-financing income compared to other general public universities. This concept is defined in this paper as university self-financing efficiency.

The following sections illustrated the literature review, research methods, empirical results, conclusions, and suggestions in sequence.

2. Literature Review

The intellectual movement advocating for university autonomy had its origins in medieval Europe. While private universities in the United States also had already established highly advanced systems of university autonomy—and even financial autonomy through sound

endowment funds—by the early years of the nation. Furthermore, with the rise of New Public Management (NPM) in the 1980s globally, European and American countries gradually began promoting financial autonomy for public universities, emphasizing efficiency and the introduction of market mechanisms. Following this trend, Asian governments such as Taiwan, Mainland China, Singapore, Japan, and South Korea and so on also progressively implemented financial autonomy reforms in their public universities during the 1990s. Hereafter, the global development in university autonomy naturally spurred academic interest in exploring the relationship between funding sources and efficiencies of higher education institutions (HEIs).

Aghion et al. (2010) investigated the relationship among university research productivity, autonomy and competitive pressure across European and American universities via employing a combination of survey methods, factor analysis, and panel regression analysis. Research productivity was measured by rankings, patents, and publication counts, respectively. The study revealed that external funding sources only contributed to higher patent and publication counts in environments characterized by greater autonomy and fiercer competition. The underlying mechanism proposed was that, under competitive pressure, external funding sources augmented universities' autonomy. This autonomy was manifested as more effective resource utilization, enhancing the competitiveness of research productivity, and thereby attracting further external funding. However, this evidence proved persuasive only in the United States. The authors therefore inferred that the lack of competitive pressure in the European public funding mechanisms resulted in lower research productivity.

Consistent with this line of inquiry, Wolszczak-Derlacz and Parteka (2011) employed DEA and regression methods to examine HEIs' efficiency and its determinants, using a sample of 259 public HEIs from seven European countries between 2001 and 2005. Their study revealed that the proportion of core funding in total revenue exerted a negative influence on efficiency. Given that the funding in their sample primarily originated from government sources, this implied that a higher share of public funding—associated with a lower proportion of external financing and weaker competitive pressure—correlated with reduced efficiency.

In a related vein, Sav (2012), applying stochastic frontier analysis (SFA), found that from 2005 to 2009, increases in public funding in the United States enhanced cost efficiency in public universities, yet diminished it in private institutions. Further extending this research, Sav (2013) utilized a two-stage DEA and Tobit model analysis over the same period and

demonstrated that higher levels of government funding were associated with increased production efficiency in U.S. public universities. Conversely, greater reliance on tuition revenue and investment returns was linked to lower efficiency.

Varga and Horváth (2013) employed a Probit model to examine the efficiency of European HEIs and its determinants between 2006 and 2008. Their findings indicated that external funding had a positive effect on the likelihood of patent applications by HEIs. Wolszczak-Derlacz (2017) utilized the DEA models to estimate and compare the efficiency of public HEIs in Europe and the United States between 2000 and 2012. The study revealed that the proportion of public funding exerted a negative influence on the efficiency of European HEIs.

In a subsequent study, Wolszczak-Derlacz (2018) applied the Malmquist productivity index and the Generalized Least Squares (GLS) panel regression model to compare the patterns and determinants of productivity change among public HEIs in ten European countries and 500 HEIs in the United States from 2000 to 2010. The results demonstrated that the share of public funding negatively affected productivity growth in European HEIs, whereas it positively influenced productivity growth in U.S. HEIs. Consistent with the argument of Aghion et al. (2010), the author suggested that the contrasting effects of public funding on efficiency could be attributed to differences in the allocation mechanisms between the two regions. In most European countries, public funding was allocated to HEIs as lump-sum grants rather than being tied to teaching and research performance. By contrast, public funding in the United States was distributed competitively based on performance. The lack of a competitive funding mechanism in Europe resulted in weaker competition pressures, which failed to incentivize HEIs to utilize resources efficiently. Consequently, public funding was inversely associated with productivity growth in European HEIs.

Chen et al. (2024) employed a super-efficient DEA-Malmquist-Tobit model to analyze the allocative efficiency of 13 first-class Chinese universities ("Double First-Class") between 2015 and 2019. The study found that while overall allocative efficiency was generally satisfactory, significant variations existed due to several influencing factors. Notably, local government funding was identified as a significant impediment to efficiency improvement. The authors hypothesized that this could be attributed to a crowding-out effect, whereby governmental financial resources displaced other social investments. Alternatively, it might reflect reduced incentives for universities to enhance resource allocation efficiency due to over-

reliance on fiscal support. Furthermore, the research revealed that while the regional economic environment could exert a positive influence on "Double First-Class" universities, this effect was not achieved merely through scaling educational resources via direct funding (Scale Efficiency, SE). Instead, it operated through Pure Technical Efficiency (PTE)—by optimizing the technological innovation environment, cultivating advanced technologies, and attracting high-level talent, thereby improving the institutions' resource allocation efficiency. This outcome underscores that how resources are utilized is the crucial determinant of productivity, suggesting that the high performance of top universities cannot be achieved solely through the accumulation of input factors (Chen, 2024b). The study concluded that efficiency improvement constitutes a systematic and comprehensive long-term transformation process, wherein single policy interventions yield limited immediate effects. Ample reserves of high-level human capital were found to facilitate the accumulation of disciplinary advantages, thereby effectively enhancing both the quality and quantity of university outputs and promoting the improvement of technical efficiency in resource allocation. Additionally, international academic exchanges were identified as a means to help universities enhance their resource allocation efficiency (Bonaccorsi et al., 2022).

In summary, Aghion et al. (2010), Wolszczak-Derlacz and Parteka (2011), Sav (2012, 2013), Wolszczak-Derlacz (2017, 2018), and Chen et al. (2024) all contended that variations in educational systems and public funding policies could shape distinct competitive environments, resulting in heterogeneous impacts of public funding on university performance. This suggested that the proportion of public funding might exert different influences on university income and efficiency depending on the structure of the educational system and the nature of public funding policies.

3. Methodology and Data

3.1 Methodology

This study leveraged the non-parametric DEA method, which requires no assumption of a functional form and is independent of measurement units. This enabled the study to assess the self-financed efficiency of the top university NTU in Taiwan between 2012 and 2023 given a minimal risk of model misspecification bias (Johnes, 1998; Schiltz & De Witte, 2017).

DEA was extended from Farrell's (1957) efficiency measurement framework with linear programming to construct an efficiency frontier from all sample units, then evaluated each

unit'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) and the model was so called the CCR model. Banker et al. (1984) later further extended this framework by comprising estimation under variable returns to scale (VRS) and the model was so called 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 were 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 mathematical programming. Their CCR model assumed constant returns to scale (CRS), implying all decision-making units (DMUs) operated at optimal scale, that was, operating at the lowest long-run average cost (LAC). This assumption inherently excluded scale-related inefficiencies. The CCR formulation is as follows,

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

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

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

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

where, z_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, $Y^{Overall}$: C × N matrix of C types of outputs for overall HEIs, $X^{Overall}$: D × N matrix of D types of inputs for overall HEIs, Y_j: C × 1 matrix of C types of outputs for the jth HEI, X_j: D × 1 matrix of D types of inputs for the jth HEI, z_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 incorporating potential scale diseconomies, establishing the BCC model. This relaxation of the CRS assumption enabled efficiency measurement under variable returns to scale (VRS), that was, increasing return to

scale (IRS) or decreasing return to scale (DRS). The BCC model was formulated as the following linear programming problem:

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

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

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

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

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

where, z_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, $Y^{Overall}$: C × N matrix of C types of outputs for overall HEIs, $X^{Overall}$: D × N matrix of D types of inputs for overall HEIs, Y_j: C × 1 matrix of C types of outputs for the jth HEI, X_j: D × 1 matrix of D types of inputs for the jth HEI, N: N × 1 vector of ones.

The technical efficiency (TE) scores derived from the CCR model assessed each HEI's efficiency relative to the sample-wide efficiency frontier. Conversely, pure technical efficiency (PTE) scores gained via the BCC model reflected efficiency independent of scale effects. As demonstrated by Banker et al. (1984), TE can be decomposed into PTE times scale efficiency (SE) as follows:

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

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

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

The efficiency scores of individual HEI are 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 it achieve technical efficiency (i.e. TE=1). Namely, a relative technical efficiency university (i.e. TE=1) behaves it possesses outstanding management, teaching and research capacities to well

use its resources (i.e. PTE=1) meanwhile produces at the stage of optimal scale, i.e. CRS (i.e. SE=1).

On the contrary, a university which is poor in management, teaching and research capabilities (i.e. with pure technical inefficiency, PTE<1), or is deviant from optimal production state (i.e. with scale inefficiency, i.e. SE<1), or both, it behaves technical inefficiency (i.e. TE<1).

For a university possessing pure technical inefficiency (PTE<1), enhancing management practices and academic capabilities (teaching & research) was essential to optimize resource utilization and improve PTE. On the other hand, for a university possessing scale inefficiency (i.e. SE<1), rearranging production state to minimize long-run average coat (LAC) was critical to optimize its scale. Moreover, if the university is at production state of IRS, namely, its proportion increases in outputs was greater than that in inputs and enjoys economies of scale, expanding outputs will further minimize its costs and hereafter optimize its scale. Conversely, a DRS production state meant the university's proportion increases in outputs is lower than that in inputs and bring it in diseconomies of scale. Hence, expanding outputs will further increase its cost burden and thus lower its SE. The university thus should cut its 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, or to reshaping its LAC curve (LACC) by altering the output mix to gain economies of scale and/or scope (Baumol, Panzar, & Willig, 1982), then its SE can be improved.

3.2 Data

In terms of construction of the efficiency frontier, since this study purposed to assess the relative self-financing efficiency of NTU, a public comprehensive university in Taiwan, and to consider the potential impact of inter-HEI heterogeneity on resource and output-input mix and avoid estimation bias (Chavas, Barham, Foltz, & Kim, 2012; Chen, 2020), only public comprehensive universities in Taiwan were adopted as a sample to construct the efficiency frontier. Specifically, the sample employed to estimate efficiency frontier yearly in this study were 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.

In terms of measurement of inputs and outputs, this research incorporated both current regulation, i.e. Taiwan's "National University Endowment Fund Establishment Act", and practical financial reporting information to align with research purpose and operational realities, avoiding measurement errors.

Wherefore inputs were measured by four variables: Teaching and research expenses (TeCost), combined expenses from academia–industry cooperation and government research grants (ReCost), Administration and general expenses (AGCost), and Net fixed assets (NFA). Among others, NFA was measured as the total stock rather than annual increments, since HEIs relied on their full fixed assets for production rather than increments.

And outputs were measured by two primary self-financing income: Tuition/fee revenue (TeRev) and Combined income from academia–industry cooperation and government research grants (ReRev). This specification allowed assessment of HEIs' financial autonomy and efficiency in generating income independently of government budget.

Overall, this measurement of inputs and outputs provided a more intuitive financial perspective for assessing universities' relative self-financing efficiency rather than overall efficiency or only research efficiency. It captured not only the quantitative effects but also the price effects embedded in self-financing performance.

In this framework, a university with PTE = 1 indicated it effectively used of the four input factors to generate the two self-financing revenue, revealing excellent management and academic capacity. On the other hand, a university with SE = 1 indicated it operated at optimal scale (CRS), i.e. at the state of minimizing LAC or said the combined growth rate of the two outputs equals that of the three costs and NFA. Whereas SE < 1 implied operation at the state of IRS or DRS, and under IRS, the combined growth rate of the two outputs exceeds that of the three costs and NFA; and under DRS, it was on the contrary.

4. Empirical Results

4.1 The Top University in Taiwan: National Taiwan University, NTU

National Taiwan University (NTU), established in 1928, is currently entering its 96th year of operation. As of the 113th Academic Year, the institution has evolved into a comprehensive university comprising 17 colleges (including the College of International Affairs, College of Liberal Arts and Social Sciences, College of Innovation and Design, College of

Advanced Science and Technology, Center for General Education, and School of Professional and Continuing Education), 3 professional schools (Dentistry, Veterinary Medicine, and Pharmacy), 61 undergraduate programs, and 152 graduate institutes. The current student enrollment stands at approximately 34,000. As of the end of 2024, NTU's total assets amounted to NT$67,122.783 million, total liabilities of NT$26,410.91 million, and net assets of NT$40,711.873 million. Property, plant, and equipment constituted the largest proportion of the assets, primarily comprising office buildings, campus housing, and various operational equipment. For a considerable period, National Taiwan University (NTU) has been the largest university in Taiwan by metrics such as total assets, net fixed assets, number of full-time teachers and student enrollment.

Furthermore, it consistently leads all Taiwanese universities in major global rankings, including such as the QS World University Rankings and the Times Higher Education (THE) World University Rankings. As Taiwan's most prestigious and leading tertiary institution, NTU has successfully attracted substantial financial investments and a concentration of top-tier talent, technology, and research infrastructure from the Taiwanese government, domestic industries, and international sources. These consolidated resources have enabled NTU to develop comprehensive and multidisciplinary strengths in fields such as Medicine and Biosciences, Electrical Engineering, Computer Science, as well as in areas aligned with Taiwan’s industrial advantages—including semiconductors and integrated circuit design.

In anticipation of its centennial anniversary in 2028, NTU is poised to elevate its institutional prestige to a new echelon. To achieve this, the university is currently engaged in a comprehensive strategic agenda that includes prioritizing the recruitment of eminent faculty and researchers, rigorously advancing institution-wide internationalization, enhancing research and development (R&D) capacity, ensuring accessible pathways for socioeconomically disadvantaged populations, and pioneering innovation in learning and pedagogy. These proactive measures are designed to significantly bolster NTU's competitive advantage in the global research and educational spheres and mitigate the risk of unpredictable marginalization on the world stage.

4.2 Self-Financing Efficiencies of NTU

This study utilized DEA along with financial analysis to assess the self-financed efficiency of the top university NTU in Taiwan Between 2012 to 2023. Table 4.1 presents NTU's efficiency scores for the 2012–2023 period. As shown, NTU consistently achieved pure technical efficiency (PTE = 1) throughout these years however, scale efficiency (SE = 1) was observed only during 2015–2017 and again in 2019. Consequently, overall technical efficiency (TE = 1) was attained exclusively in those years. Taken together, these findings indicate that NTU maintained substantial managerial, instructional, and research capabilities, yet operated under decreasing returns to scale (DRS) inefficiency during most of the study period. Moreover, although NTU's scale efficiency improved steadily from 2012 to 2014—reaching an optimal scale in 2015–2017 and once more in 2019—it subsequently reverted to a DRS production regime. This reversion suggests that, when mobilizing the four principal inputs to generate its two main streams of self-financing income, NTU frequently faced a scenario in which the aggregate growth rate of inputs exceeded that of self-financing revenues.

Table 4.1: *DEA efficiency scores of NTU from 2012 to 2023*

Public Comprehensive HEIs Efficiency Frontier													
Efficiency	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Mean**
TE	0.948	0.968	0.992	1.000	1.000	1.000	0.995	1.000	0.954	0.982	0.95	0.967	0.980
PTE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SE	0.948	0.968	0.992	1.000	1.000	1.000	0.995	1.000	0.954	0.982	0.95	0.967	0.980
State	DRS	DRS	DRS	CRS	CRS	CRS	DRS	CRS	DRS	DRS	DRS	DRS	

4.3 Financial Data Analysis of NTU

To achieve a more comprehensive and in-depth understanding of NTU's financial structure and status, this study performed a detailed financial analysis of the university. This analysis specifically included an examination of the composition of its inputs and outputs, as well as their yearly growth rates, the results of which are summarized in Table 4.2 and Table 4.3, respectively. The findings reveal that during 2012–2023, NTU recorded a surplus only in 2022 and 2023, while all other years posted deficits, with an average net loss of NT$431.67 million over the 12-year period. Nonetheless, the deficits steadily declined, as reflected in an average annual growth rate of net loss of –26.16%. On the revenue side, self-financing income accounted

for an average of 62.32% of total income, showing negative growth only in 2018 and 2020–2021, with an average annual growth rate of 0.72%. These results indicate that NTU's capacity to generate self-financing income improved continuously during 2013–2017, 2019, and 2022–2023, which partially explains why the university achieved scale efficiency—i.e., operated at the optimal scale (SE = 1)—in 2015–2017 and 2019.

Furthermore, both the proportion of teaching self-financing income to total revenue and its annual growth rate were substantially lower than those of research self-financing income. The 12-year average for the former was 11%, with an average annual growth rate of 0.14%, while the latter had a 12-year average of 37.34% and an average annual growth rate of 0.51%. This indicated that NTU primarily relies on research activities to generate self-financing income, and this reliance has shown an increasing trend over time.

When examined by year, the proportion of teaching self-financing income to total revenue exceeded the average (11%) in the years 2012–2016 and 2021, and showed negative growth in 2014, 2016, 2018-2019, 2022. In contrast, the proportion of research self-financing income to total revenue was above its average (37.34%) in 2014–2016, 2018, and 2021, and showed negative growth in 2016-2017, 2019-2020, 2022. Inconsistent with the findings of Varga and Horváth (2013), Wolszczak-Derlacz (2018) and Chen et al. (2024), the results of this study did not identify a definitive relationship between the self-financing ratio and efficiency. Specifically, an annual increase in the self-financing ratio did not consistently correspond with an improvement nor a decay in efficiency.

On the other hand, among NTU's factor inputs, the 12-year averages of TeCost, ReCost, and AGCost as a proportion of total cost were 41.74%, 35.68%, and 9.20%, respectively. Their average annual growth rates over this period were -0.09%, 0.62%, and -1.96%, respectively. This revealed that although teaching activities contributed relatively little to self-financing income, they constituted the primary expenditure for NTU, far exceeding the average proportion of teaching income (11%). However, this disparity was gradually improving, as the average annual growth rate of teaching income as a share of total revenue (0.14%) was significantly higher than that of teaching cost as a share of total cost (-0.09%).

Conversely, the average proportion of research income to total revenue (37.34%) was slightly higher than the average proportion of research cost to total cost (35.68%). Nevertheless, this marginal advantage was weakening, as the former's average annual growth rate (0.51%) was

slightly lower than that of the latter (0.62%). These findings demonstrated that NTU's self-financing efficiency in teaching was far lower than that in research. Furthermore, when examined by year, the proportion of teaching cost to total cost was below the average (41.74%) from 2015 to 2020. In comparison, the proportion of research cost to total cost fell below its average (35.68%) only in 2012–2015, 2017, and 2022.

In terms of individual output amounts, the average of TeRev was NT$1,955 million, with an average annual growth rate of 2%. Negative growth in its annual rate occurred only in 2014 and during 2016–2017. Meanwhile, the average of ReRev was NT$6,642 million, with an average annual growth rate of 2.5%. Negative growth in its annual rate was observed only in 2013, 2016, and 2020.

In terms of individual factor inputs, the average values and average annual growth rates of TeCost, ReCost, AGCost, and NFA were NT$7,609 million, NT$6,508 million, NT$1,670 million, and NT$30,991 million, and 1.53%, 2.25%, –0.37%, and 1.99%, respectively. Among these, NFA recorded the highest average annual growth rate. Moreover, Negative growth in the annual rate of TeCost occurred in 2013–2016 and 2018, while ReCost experienced negative growth in 2013, 2017, and 2020. Similarly, AGCost showed negative growth in 2013–2014, 2016, 2018, 2020, and 2023, and NFA saw declines in 2014–2015, 2018, and 2022. These fluctuations reflected ongoing challenges in optimizing the cost structure and effectively managing institutional resources.

A comparative assessment of the outputs and inputs of teaching and research activities revealed several noteworthy patterns. Specifically, NTU’s annual growth rate of teaching revenue exceeded that of teaching costs in 2013, 2015–2016, 2018–2021, and 2023, while the annual growth rate of research revenue surpassed that of research costs in 2013–2015, 2017, 2019–2021, and 2023. As a result, the average annual growth rate of TeRev (2%) was slightly higher than that of TeCost (1.53%), indicating increasing returns to scale (IRS) in teaching, whereas the average annual growth rate of ReRev (2.5%) was marginally higher than that of ReCost (2.25%), indicating IRS in research. Taken together, these findings help explain why NTU achieved scale efficiency (SE = 1) in 2015–2017 and 2019.

In particular, in 2015 and 2019 both teaching and research displayed IRS, offsetting the effects of rising AGCost and/or NFA. By contrast, in 2016 IRS in teaching and a sharp 3.23% reduction in NFA counterbalanced the effects of DRS in research. Similarly, in 2017

strong IRS in research neutralized the simultaneous increases in AGCost and NFA. However, in 2013, 2020–2021, and 2023, substantial increases in NFA (5.69% in 2013, 3.56% in 2020, and 0.29% in 2023) or simultaneous increases in both AGCost and NFA (0.67% and 2.61%, respectively, in 2021) produced overall DRS even though both teaching and research exhibited IRS in these years.

When considered alongside the student population growth rate, it was observed that the average annual growth rates of TeRev and TeCost at NTU (2% and 1.53%, respectively) were higher than the average annual growth rate of the student population (0.66%). This indicated that NTU not only demonstrated resilience against the impact of declining birthrates—maintaining positive growth in student numbers—but also increased both tuition prices and per-unit teaching costs at a rate exceeding that of student enrollment growth.

However, given that NTU's self-financing teaching income remained substantially lower than its teaching costs, and considering the ongoing trend of demographic decline, it appears imperative for the government to grant national universities greater flexibility in pricing. Such a policy would help ensure both the educational and research quality of national universities and their financial health, thereby supporting sustainable development and enabling them to fulfill their social responsibilities.

Nevertheless, when also taking into account the value of educational equity and social justice, it becomes evident that increased government funding for public universities in Taiwan is essential. If even NTU—the most resource-endowed and highest-quality university in Taiwan—faces challenges in financial sustainability amid severe sub-replacement fertility and widening wealth inequality, other public universities likely confront even more critical fiscal challenges.

Table 4.2: *Inputs and Outputs Analysis of NTU*

unit: NT$ million, %, Person

Variable	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Mean
TR	16822	16592	16540	16678	16679	16977	17386	19018	18352	16896	20543	21190	17806
SFR	9950	10037	10326	10474	10616	10967	11132	12229	11408	9810	12854	13481	11107
TeRev	1867	1943	1834	1873	1840	1787	1789	1861	2013	2140	2207	2303	1955
ReRev	6003	5945	6203	6342	6274	6320	6619	7084	6756	7034	7297	7826	6642
TC	17603	17290	17221	17328	17318	17587	17987	19278	18577	17307	20198	21159	18238

TeCost	7680	7557	7253	7230	6934	7141	7100	7295	7521	7931	8659	9002	7609
ReCost	6000	5909	6046	6158	6256	5975	6542	6983	6636	6860	7144	7590	6508
AGCost	1731	1675	1657	1675	1643	1663	1634	1730	1633	1644	1702	1653	1670
NFA	26148	27636	27614	27417	28303	29479	29461	37022	38341	39341	30523	30610	30991
Sur/Def	-781	-698	-681	-650	-639	-610	-601	-260	-225	-411	345	31	-432
R_SFR	59.15	60.49	62.43	62.8	63.65	64.6	64.03	64.3	62.16	58.06	62.57	63.62	62.32
R_TeRev	11.1	11.71	11.09	11.23	11.03	10.53	10.29	9.79	10.97	12.67	10.74	10.87	11.00
R_ReRev	35.69	35.83	37.5	38.03	37.62	37.23	38.07	37.25	36.81	41.63	35.52	36.93	37.34
R_TeCost	43.63	43.71	42.12	41.72	40.04	40.6	39.47	37.84	40.49	45.83	42.87	42.54	41.74
R_ReCost	34.09	34.18	35.11	35.54	36.12	33.97	36.37	36.22	35.72	39.64	35.37	35.87	35.68
R_AGCost	9.83	9.69	9.62	9.67	9.49	9.46	9.08	8.97	8.79	9.5	8.43	7.81	9.20
NoStud	31545	30972	30622	30566	31783	31802	31745	31945	32527	32923	33422	33882	31978

Note1: **TR** denoted total revenue; **SFR** denoted the sum of all self-financing revenue; **TeRev** denoted self-financing revenue from teaching activities; **ReRev** denoted self-financing revenues from research activities; **TC** denoted total costs; **TeCost** denoted teaching and research expenses; **ReCost** denoted combined expenses from academia–industry cooperation and government research grants; **AGCost** denoted administration and general expenses; **NFA** denoted net fixed assets; **Sur/Def** denoted financial surplus or deficit, which was **TR** minus **TC**; **R_SFR** denoted self-financing revenue ratio, which was computed by **SFR/TR**; **R_TeRev** denoted ratio of self-financing revenue from teaching activities, which was computed by **TeRev/TR**; **R_ReRev** denoted ratio of self-financing revenue from research activities, which was computed by **ReRev/TR**; **R_TeCost** denoted ratio of combined expenses from academia–industry cooperation and government research grants, which was computed by **ReCost/TC**; **R_AGCost** denoted ratio of administration and general expenses, which was computed by **AGCost /TC**; **NoStud** denoted number of student.

Note2: Regarding self-financing revenue (**SFR**), only those derived from teaching (**TeRev**) and research (**ReRev**) activities were used to estimated DEA efficiencies; other sources such as investment income were excluded due to their minimal contribution to total revenue. A similar approach was applied to the presentation of inputs. Therefore, the sum of TeRev and ReRev was not equal to SFR. The same was true for the cost side.

Data source: Financial statements of NTU; Taiwan's college and university affairs information disclosure platform.

Table 4.3: *Yearly Growth Rate of Inputs and Outputs Analysis of NTU*

unit: %

Variable	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Mean
TR	-	-1.37	-0.31	0.83	0.01	1.79	2.41	9.39	-3.5	-7.93	21.58	3.15	2.37

SFR	-	0.87	2.88	1.43	1.36	3.31	1.5	9.85	-6.71	-14.01	31.03	4.88	3.31
TeRev	-	4.07	-5.61	2.13	-1.76	-2.88	0.11	4.02	8.17	6.31	3.13	4.35	2.00
ReRev	-	-0.97	4.34	2.24	-1.07	0.73	4.73	7.03	-4.63	4.11	3.74	7.25	2.50
TC	-	-1.78	-0.4	0.62	-0.06	1.55	2.27	7.18	-3.64	-6.84	16.7	4.76	1.85
TeCost	-	-1.6	-4.02	-0.32	-4.09	2.99	-0.57	2.75	3.1	5.45	9.18	3.96	1.53
ReCost	-	-1.52	2.32	1.85	1.59	-4.49	9.49	6.74	-4.97	3.38	4.14	6.24	2.25
AGCost	-	-3.24	-1.07	1.09	-1.91	1.22	-1.74	5.88	-5.61	0.67	3.53	-2.88	-0.37
NFA	-	5.69	-0.08	-0.71	3.23	4.16	-0.06	25.66	3.56	2.61	-22.41	0.29	1.99
Sur/Def	-	-10.63	-2.44	-4.55	-1.69	-4.54	-1.48	-56.74	-13.46	82.67	-183.94	-91.01	-26.16
R_SFR	-	2.27	3.21	0.59	1.35	1.49	-0.88	0.42	-3.33	-6.6	7.77	1.68	0.72
R_TeRev	-	5.5	-5.29	1.26	-1.78	-4.53	-2.28	-4.86	12.05	15.5	-15.23	1.21	0.14
R_ReRev	-	0.39	4.66	1.41	-1.08	-1.04	2.26	-2.15	-1.18	13.09	-14.68	3.97	0.51
R_TeCost	-	0.18	-3.64	-0.95	-4.03	1.4	-2.78	-4.13	7	13.19	-6.46	-0.77	-0.09
R_ReCost	-	0.26	2.72	1.22	1.63	-5.95	7.07	-0.41	-1.38	10.97	-10.77	1.41	0.62
R_AGCost	-	-1.42	-0.72	0.52	-1.86	-0.32	-4.02	-1.21	-2.01	8.08	-11.26	-7.35	-1.96
NoStud	-	-1.82	-1.13	-0.18	3.98	0.06	-0.18	0.63	1.82	1.22	1.52	1.38	0.66

Note1: the notations in this table were as those in Table 4.2. Data source: Calculated by the author based on Table 4.2.

5. Conclusion and Suggestion

Throughout the period from 2012 to 2023, National Taiwan University (NTU) consistently achieved pure technical efficiency (PTE = 1). However, it attained scale efficiency (SE = 1) in only a few years, resulting in overall technical efficiency (TE = 1) being achieved only sporadically during this timeframe.

The scale inefficiency observed was consistently attributable to decreasing returns to scale (DRS), indicating that NTU was operating at a scale too large to maintain efficiency. It is therefore recommended that NTU consider downsizing its operational scale or altering its output mix to shift or reshaped the long-run average cost (LAC) curve, thereby moving toward optimal scale and improving scale efficiency.

Furthermore, this study found that NTU sustained financial deficits throughout most of the period, only achieving a surplus since 2022. A detailed examination revealed that these deficits primarily originated from teaching activities. Although NTU demonstrated resilience

against declining student enrollment—maintaining positive growth in student numbers—and increased both tuition fees and per-unit teaching costs at rates higher than the student population growth rate, its self-financing teaching income remained substantially lower than teaching costs.

In light of persistent demographic decline, it is suggested that the government consider granting public universities greater tuition pricing flexibility. Such a measure would help ensure the quality of education and research, strengthen financial stability, and support sustainable development while enabling universities to fulfill their social responsibilities.

However, if the social justice value of equal educational opportunity is also taken into account, then it is clear that the government should instead increase financial support for public universities. This is particularly crucial in a society like Taiwan, which is grappling with a shrinking student population and a widening wealth gap. If a top-tier institution like NTU, with its abundant and high-quality resources, faces such financial sustainability issues, it suggests that the challenges of financial stability and sustainability for other public universities are likely to be far more severe.

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