

Whether Post-Merger Higher Education Institutions Operate Efficiently in the Long-Run? A Follow-up Study in Taiwan

Chiou Rung Chen

Department of Educational Management, National Taipei University of Education, Taiwan, China
Email: ccr0720@gmail.com

Abstract—This study applied DEA to verify the effects of mergers on the three cases of HEIs in Taiwan from 2012 to 2020. The results revealed NKUST's merger promoted his PTE. Though, that was not the case in other mergers. The efficiency HEI can still maintain its PTE, as shown as NPTU, whereas inefficiency HEI became more inefficient, as shown as NTHU. Moreover, although the merger may bring in economies of scale and scope, the effects cannot be sustained, as shown as NPTU and NKUAS. Indeed, from the lengthy perspective, all of them experienced diseconomies of scale and scope, among others, NTHU and NKUST have been even into DRS. Finally, the TE of all three HEIs decayed, and both of the SE and TE did not yet recover to the levels before the mergers, by 2020. To sum up, the results recommended governments and HEIs should be prudential on the mergers of HEIs, especially in Taiwan suffering from the vivid and persistent drops in fertility rates. Moreover, HEIs should capitalize on their multi-field, interdisciplinarity, and multi-campus to develop and innovate the new courses, programs, and research meeting the needs of the times, and optimize their SE by the economy of scope.

Keywords—Higher Education Institutions (HEIs), merger, Data Envelopment Analysis (DEA), Technical Efficiency (TE), Pure Technical Efficiency (PTE), Scale Efficiency (SE), economy of scale, economy of scope

I. INTRODUCTION

Since the mid-to-late 1980s, the birth rate and fertility rate in Taiwan have declined significantly, from 23.38% and 2.5% in 1980 to 16.55% and 1.8% in 1990. Since then, the situation has gotten worse, reaching 6.55% and 0.98% respectively by 2021. Negative population growth has already begun in 2020. However, the Ministry of Education in Taiwan ignored this important indicator when formulating relevant education policies. From 1994 to 2005, the Ministry implemented a universal higher education policy to expand the number of colleges and universities by upgrading and establishing new ones. This foreshadowed the crisis of higher education in Taiwan in recent years. Fewer children and a large number of Higher Education Institutions (HEIs) have resulted in the

oversupply of Higher Education (HE), HEIs are faced with a shortage of students and a sharp decline in tuition income. To make matters worse, Taiwan's HEIs have long relied on tuition fees and the government budget as their main source of funding. Some HEIs have been faced with financial crisis, and have even been ordered to halt to operation or recruitment. By 2022, 12 HEIs had ceased operations or stopped recruiting students. According to preliminary estimates by Taiwan's Ministry of Education, at least 40 HEIs are expected to fail in the next 8 years.

Coping with the shortage of students and the sharp drop in tuition revenue, the Ministry of Education of Taiwan announced the "Measures for the Integration of National Universities" to promote the integration of national universities in 2012. Small number of HEIs have merged to boost resources and competitiveness. Until 2020, four cases of post-merger HEIs in Taiwan are University of Taipei (UT), National Pingtung University (NPTU), National Tsing Hua University (NTHU), and National Kaohsiung University of Science and Technology (NKUST). However, to date, few empirical studies have explored and tracked the impacts of mergers on HEIs in Taiwan.

Chen [1] revealed no significant efficiency improvement from the two cases of post-merger in Taiwan. That was consistent with the implications from [2, 3]. Fu *et al.* [2] confirmed that all kinds of universities in Taiwan were already in the production states of Decreasing Return to Scale (DRS) over 2000–2003. That forecasted that HEIs in Taiwan, which were suffering decreasing fertility rate together with plenty of HEIs after 2000, were very difficult to enhance their efficiency and address higher education crisis by merger in the long-run. Also, Chen [3] revealed that to improve overall operational efficiency, public comprehensive and technical universities and private technical universities must promote their efficiency in management and in teaching and research, and must optimize the scale of operation simultaneously. Instead, private comprehensive must first optimize their scale. Chen [3] thus highlighted the merger which cannot improve efficiency in management and in teaching and research, or even lead to the production state into DRS, will not help HEIs in Taiwan to address the higher education crisis caused by low fertility rates.

Although Chen [1] has made a preliminary verification on HEIs' mergers in Taiwan, the study was restricted by limited post-merger samples and data period, verified only two cases of merged HEIs, and even one of the post-merger universities included the data of only one year after the merger. However, a growing number of studies exploring different countries and periods of time shed light on that 'time' was a critical dimension to realize the consequences of HEIs' mergers, which needs to be paid attention to. Long-run tracking is thereby required in relevant studies.

In terms of efficiency, Hu and Liang [4] and Mao *et al.* [5] found positive effect of merger on efficiency and productivity in the first year after the merger, but not in the subsequent years in China. Similarly, Capuccinello and Bradley [6] showed that mergers before 2006 reduced student dropout risk while mergers from around 2006 onwards increased dropout risk. In addition, the undesired effects of merger persisted for 1–2 years and varied with programs in the UK. Also, Papadimitriou and Johnes [7] revealed that mergers only lead to efficiency gains in UK HEIs for about one year, followed by a decline, and they therefore called for the government to be wary of merger policy about HEIs. Consistently, Johnes and Tsionas [8] also revealed that the efficiency upgraded following a merger appeared just at the beginning and then disappeared soon after the merger. By observing the HEIs mergers in Europe, Estermann and Pruvot [9] argued it was lengthy that the expected benefit of a merger, such as more efficient use in resources, progress in research and teaching, better organization management and centripetal force and so on, came out, and even possibly, the benefit may never materialize. The underestimating of 'time' from people may even degrade the efficiency following the merger. Also, Zhang and Worthington [10] highlighted that studies using smaller sample sizes or emerging country samples tend to be more likely to show the evidence of scope economy.

More studies stressed the crucial role of time in HEIs merger were from the perspective of cultural integration and identity. Goedegebuure [11] investigated the HEIs' mergers in Australia and Netherlands from the macro (national) and meso (institutional) levels and indicated that a merger needed about 10 years to settle down. Pritchard and Williamson [12] traced the merger case of the University of Ulster in Northern Ireland from micro (individual) levels and concluded that the University of Ulster still did not fully unify from the perspective of both of academics and administrators even after over 20 years. Consistently, from the perspective of micro-levels, two researchers from Finland, Tienari *et al.* [13] analyzed the merged case of the Aalto University in Finland, and Ursin and Aittola [14] inquired four merger cases of Finnish university in Finland, both of them argued that cultural integration and identity following a merger were costly in time. Leslie *et al.* [15] tracked the merger case of a for-profit university (MERU) in the US which was merged in 2001 and also made a similar conclusion it was more difficult and lengthy than people expected on cultural

integration following the merger. Recently, Wollscheid and Røsdal [16] reviewed 21 studies from different countries and highlighted the impacts of mergers on HEIs may indirectly change what they called micro-level processes, that was, the change in cultural integration, academic identities, emotions and perceptions, and teaching and research from the perspective of staff, and they thereby argued that it was needed a long-term perspective involving students, staff and quantitative indicators to demonstrate the merger consequences. Obviously, we need longer sample period after merger and more samples to comprehend the whole picture about the long-run effect of merger on HEIs in Taiwan and the long-run development of HEIs after their mergers.

Besides considering 'time' dimension, this study attempted to be unrestricted by model specification as could as possible to avoid biased estimation [10, 17, 18] and therefore adopted the nonparametric methodology, Data Envelopment Analysis (DEA), to perform empirical examination. Moreover, considering the channel diversity of impacts of merger on HEIs as mentioned by previous researches [1, 3, 19], what linked merger to efficiency was also interested to be verified. Finally, Papadimitriou and Johnes [7] and Chen [1] both found that only the merger of efficiency HEIs can enhance or maintain operational efficiency of merged HEIs. They therefore concluded that government policies should encourage the merger of efficiency HEIs, rather than allowing the merger of HEIs with poor efficiency. The nonparametric DEA allowed this study to decompose Technical Efficiency (TE) to Pure Technical Efficiency (PTE), which reflects the capacity of management and research and teaching, and Scale Efficiency (SE), which reflects the degree of scale optimization, and thereby did a favor for this study to clarify how and by which factor a merger impacted efficiency of the post-merger HEIs.

To sum up, to better demonstrate the long-run effect of the merger on the operational efficiency of the HEIs and the subsequent development of post-merger HEIs, and therefore provide precise and full reference to policymakers and HEIs, this study aimed to follow up [1] research, besides extending sample period to 2020, further added new post-merger HEIs, NKUST as study case. In addition, by applying the nonparametric DEA method, this study sought to demonstrate from long-run perspectives the channels linking merger and efficiency and further to re-examine, after the merger, whether only efficiency HEIs can operate efficiently, while inefficiency HEIs can only get worse. All in all, this study adopted DEA method to verify what happened and how to happen to the efficiency of three cases of post-merger HEIs in Taiwan, specifically, from the long-run perspective, with the data from 2012 to 2020.

The remainder of the paper was organized as follows. Section II reviews previous literature. Section III describes the methodology and the three cases of post-merger HEIs. Section IV presents empirical results, and Section V provides conclusions and suggestions.

II. LITERATURE REVIEW

The so-called technical efficiency institution refers to the institution with good management ability and the optimal size. It is manifested in the ability to make good use of his various resources to R&D, produce and market its high-quality products or services, so as to maximize the output under a given factor input or minimize the cost under a given output. In terms of HEIs, due to the characteristics of university autonomy, that is, co-governance by management and faculty, an efficiency HEI is one that makes the best use of financial and non-financial resources in innovation, production and marketing of quality teaching and research (i.e., good ability in management and in teaching and research, and is so-called pure technical efficiency, PTE, in DEA) at a long-run cost-minimized scale (i.e., optimal scale, and is so-called scale efficiency, SE, in DEA) by management and faculty.

Generally speaking, the merger will expand the post-merger HEI's scale, however, its expected benefit, such as the complementary effect from pre-merger HEIs, staff and faculty, and students may promote better use of resources and hence minimize cost under the given revenue, and the possible economies of scale and scope to make the Long-Run Average Cost (LAC) decrease with enlarged scale and expanded variety of products, all of these may not occur. Besides, even if these happen, the proportion increase in costs caused by the merger may exceed that in revenues, thereby shown as the TE decays following the merger [9]. This study highlighted that merger does enlarge scale, and may increase financial and non-financial resources, or rich diversity in fields and interdisciplinary integration, cause multi-campus and even Transnational HEIs, however, if the merger can neither make the post-merger HEI to enhance the ability to use a variety resources, nor optimize the post-merger HEI's scale, then the merger not only cannot aid in improving operational efficiency, and even worsens the teaching and research in the post-merger HEI.

In light of this, what the mixed effect of a merger on HEIs as well as what and how the channels link mergers to efficiency in the post-merger HEIs, that is, whether the merger enhances TE score by upgrading PTE score, which is manifested in better use of financial and non-financial resources to optimize efficiency in management and in teaching and research after the merger and thus minimize cost under the given revenue, or by upgrading SE score, which is manifested in optimizing scale to as could as possible minimize LAC, i.e. make the production in the state of Increasing Return to Scale (IRS) or Constant Return to Scale (CRS) after the merger, these issues are still ambiguous and need to be further verified. Most previous studies either only inquired what the possible factors impacted efficiency though lack of examination on post-merger HEIs, or only investigated the motivation, process and consequence of HEIs' mergers, few of them clearly clarified the channels link mergers to efficiency. Namely, few of them empirically demonstrate what and how the mergers impacted efficiency in the post-merger HEIs. The application of DEA just makes up for this gap.

To well compare the results of this study to those from previous studies, this study reviews literature in terms of the impacts of the mergers on PTE and SE respectively and as follows.

A. *The Possible Factors Linking Merger to PTE*

Merger may enhance TE score by raising PTE score. The rationale is that merger usually leads to HEIs have more resources to use, comprising financial and non-financial, and may have more opportunities to optimize resources use through the complementation among pre-merger HEIs, staff (both of administrators and faculty) and students. More and better use of resources, both optimizing quantity and allocation, resulting in higher efficiency in management efficiency and in teaching and research, such as better innovation and more student-oriented in teaching, and higher research productivity, both in quantity and/or quality. That thereby upgrades PTE, and a higher PTE score following the merger will display.

Though, merger may induce much more complexity and costs in meso-levels (i.e., among institutions of the pre-merger HEIs) and micro-levels (i.e., among the individuals of the pre-merger HEIs, including staff, faculty, and students). That thus may result in more though poor use of resources due to higher complexity or inconsistent in missions, culture integration, and academic identity, and much more stress on staff and so on, leading to poor efficiency in management and in teaching and research. That thereby degrades PTE, and a lower PTE score following the merger will show.

Some of the factors derived from the mergers could promote better use of resources in the post-merger HEIs, which can manifest itself in better ability in management and in teaching and research and thus the higher PTE score after the mergers. First of all, different funding sources may have diverse effects on the use of resources for HEIs. Merger may make post-merger HEIs have more and better use of resources and thus upgrade the PTE in the post-merger HEI. That may be due to more and stricter supervision and administration by competent government authorities or grantors of industry-academy cooperation, higher competitive pressure caused by competitive public-funding policy, and external funding [20]. Or due to the diversity in fields and in interdisciplinary integration [21], diversity in mission, i.e., from monotonic academic identity to multiple identities [22] and the diversity in geographical locations (multi-campus, Cross-border HE, or transnational HE (TNHE)) [23], so as to make the post-merger HEIs to attract more outstanding faculty and students to gather together. Or the well-integrated in cultural identity, mission, affective commitment [24–26] from the perspective of meso-level and micro-level. If so, a higher PTE score following the merger will be revealed due to the better use of resources.

Zha [27] pointed out that public funding of Chinese universities usually depends on the size and research productivity of the university. That implied a merger, which often came with greater scale, could help the HEIs in China have easier access to more public funding and thereby upgrade research productivity. Cai and Yang [28] indicated although Chinese HEIs were mainly dependent

on public funding, the regional comprehensive universities which have completed mergers in the past decade and were located in economically developed eastern provinces, such as the University of Suzhou and the University of Jiangnan, derived nearly half of their research income from society and industry. This was quite different from [29]'s finding, since he found no significant increase in non-governmental funding in any kind of mergers in China until 2006. However, both of them did not demonstrate the association between funding and efficiency after the merger.

Johnes and Tsionas [8] adopted dynamic Bayesian model which organized around the use of Markov chain Monte Carlo (MCMC) to examine the relationship between efficiency and merger with the sample of 25 cases of merged UK HEIs from 1996–97 to 2008–09. They stated that mergers usually contribute to access more funding, for example, the University of Manchester generated via merger received £10 million from HEFCE's Strategic Development Fund (now called the Catalyst Fund) and a further £10 million in repayable grants. However, their methodology and available data did not allow them to verify whether more funding caused by the merger promote better use and thus enhance efficiency.

Aghion *et al.* [30] used surveys together with factor and panel regression analyses to investigate the association of European and American HEIs' research productivity with autonomy and competitive pressure, in which, the research productivity was measured with ranking, patents, and publications, respectively. The study highlighted that the external sources of funding aided in enhancing patents and publications only under more autonomy together with a higher competition context. The rationale was that given the competitive pressure, external sources of funding strengthened the autonomy of the university, which was revealed as the more efficient use of resources to enhance their competitiveness in research productivity in order to strive for more external funding. However, the evidence was convincing only in the US. The author thus inferred that the lack of competitive pressure in European public grant mechanism resulted in less research productivity. The results therefore suggested that given the full autonomy together with the competition environment, if the mergers made the post-merger HEIs to absorb more external funding, then could be conducive to improving the use of resources and thus PTE after the merger.

Consistently, Wolszczak-Derlacz and Parteka [21] adopted the DEA and regression method to explore the efficiency and its determinants with the sample of 259 public HEIs from 7 European countries from 2001 to 2005. The study revealed that the proportion of core funding in total revenues had a negative effect on efficiency. Since the predominant funding for their sample was from the government, that implied the higher ration of public funding, namely, the lower ration of external funding, the lower competitive pressure, the lower the efficiency. Sav [31] used Stochastic Frontier Analysis (SFA) and showed that more public funding enhances cost efficiency in public HEIs but worsens that in private ones in the US from 2005 to 2009. Sav [32] used DEA and a Tobit two-stage analysis and demonstrated the more government funding the higher

production efficiency, nevertheless, the more dependence on tuition revenue and investment income the lower the efficiency in the US public HEIs during 2005–2009. These results implied mergers that contribute to diversifying funding sources rather than relying on tuition revenue may promote better use of funding, therefore, may upgrade efficiency in post-merger HEIs.

Varga and Horváth [33] utilized the Probit model to investigate the European HEIs' efficiency and determinants of efficiency from 2006 to 2008 and showed that external funding has the positive effect on the probability of HEIs' patenting. Wolszczak-Derlacz [34] employed DEA to estimate and compare the TE of public HEIs in Europe and in the US over the period of 2000–2012. The study found the negative effect of proportion of public funding on efficiency in European HEIs.

Wolszczak-Derlacz [35] applied Malmquist index methodology and Generalized Least Squares (GLS) panel regression to compare the patterns and causes of productivity changes of 500 public HEIs in 10 European countries and the US from 2000 to 2010. The results showed the proportion of public funding had a negative effect on the productivity growth of the European HEIs, though had a positive effect on that of the US HEIs. The author, consistent with [30], explained that the opposite effect of public funding on efficiency may stem from the different mechanisms by which public funding was allocated between the US and European countries. In most European countries, public funding was allocated to HEIs in a lump sum rather than on the basis of teaching and research performance, whereas in the US public funding was competitively allocated on the basis of performance. The lack of competitive funding mechanism in Europe led to less competitive pressure, which was unable to effectively motivate HEIs to use resources effectively, thus failing to improve their efficiency, as a result, public funding shows an inverse relationship with productivity growth.

Finally, Papadimitriou and Johnes [7] used a two-stages DEA and random effect panel data estimation method to estimate the efficiency of UK HEIs and to further explore how the mergers and other possible factors influenced efficiency from 1996 to 2013. The study found that merger enhances the efficiency of HEIs mainly by better use of administrative resource, though what drove most mergers was not their poor performance. In addition, the benefit from merger was just one-year effect after the merger and then the efficiency degraded. They thus speculated that merger may typically attract short-term funding from Higher Education Funding Council for England and resulted in the short-run benefit on efficiency. Finally, they showed the higher proportion of funding from the government, the lower technical efficiency.

However, Ripoll-Soler and de-Miguel-Molina [36] used content analysis and semi-structured in-depth interviews to explore the critical factors to merge successfully, post-merger ranking in 2018, and challenges suffered by the post-merger HEIs with the sample of 5 HEIs who aimed to upgrade ranking in the EU. They showed that Aalto University in Finland and University of Manchester in the

UK, the former aimed to attract more talented faculty and student to strengthen its competitiveness, the latter aimed to enhance research productivity to achieve international relevance, attract more funds and upgrade rank, both of them accessed more public-funding and moved into the Top 100 after the mergers.

In sum, the studies of [7, 21, 28, 30–32, 34, 35], all claimed that the discrepancy in the educational system and public-funding policy may form different competitive environments, which thus led to various effect of public-funding on performance of HEIs. That thus implied the possible different effect of the merger on the proportion of public-funding to total revenue, and efficiency, depending on the educational system and public-funding policy.

Besides the competition for public or other external funding, the competitive pressure caused by lower market power could influence the use of resources in post-merger HEIs. De Fraja and Valbonesi [37] employed a general equilibrium model to propose that the alleviated competitive pressure due to higher market power could lead to post-merger HEIs' poor use of resources and thus degrade their TE. Nevertheless, Russell [38] adopted a differences-in-differences (fixed-effect panel models) methodology together with conversations with administrators to investigate the impacts of consolidations within the University System of Georgia, including Georgia's public system of state colleges and universities in US from 2007 to 2015. The study found the alleviated competitive pressure caused by higher market share following the merger did bring in more funds to post-merger HEIs in the US, however, they did not abuse their funds, rather, they used their fund better and led to better teaching performance revealed as higher student retention rates and on-time graduation rate after the consolidation.

Secondary, the voluntary of the merger could also affect the use of resources in post-merger HEIs. Capuccinello and Bradley [6] employed the propensity score matching method and difference-in-differences method to inquire the impacts of college merger on the probability of student dropping out in the UK from 2002 to 2009. The results showed that mergers before 2006 reduced dropout risk while mergers from around 2006 onwards increased dropout risk. Since mergers before 2006 were voluntary and that after 2006 typically pushed by government pressure aimed to promote cost efficiency, they concluded that involuntary mergers could impair quality teaching. Ripoll-Soler and de-Miguel-Molina [36] analyzed the 4 voluntary merger cases in the EU and found all of them successfully moved into the Top 100 after the merger. These results were consistent with the proposition of [26, 39, 40], however, were inconsistent with [38] evidence from the US and [36] evidence from Aalto University in Finland. Russell [38] revealed that the involuntary-merger HEIs were more intended to cost-cutting to meet the governmental requirements, and thereby used their resources more efficiently, leading to higher productivity in post-merger HEIs which was revealed in the enhanced quality of teaching under the given costs.

Thirdly, diversity in fields and interdisciplinary integration, diversity in missions (i.e., from monotonic

academic identity to multiple identities), and diversity in geographical locations (multi-campus, Cross-border HE, or transnational HE (TNHE)) could impact the use of resources in the post-merger HEIs. If a merger induces increased diversity in fields and interdisciplinary integration [21], in missions [22], and in geographical locations [23], then the post-merger HEI may attract more excellent staff (comprising administrator and faculty) and students to gather together, and more industrial cooperation, therefore could promote better use of resources, and thereby is revealed as a progress in PTE score. For example, a multi-campus HEIs' merger may not only expand the area, which may promote better use of space, thus ensuring quality education and research, but also include better campus locations, which can attract more and better faculty and students, and industrial cooperation, thus promote better uses of resources in education and research. All of these contribute to the PTE upgrade following the merger.

Kyvik and Stensaker [41] drew on a series of merger initiatives in Norwegian HE and argued that the vertical mergers between HEIs with more diverse academic fields and stronger support services, made more choices for students and an enhanced capacity for organizational flexibility and international competitiveness. Wolszczak-Derlacz and Parteka [21] found that the number of different faculties had positive effect on efficiency in public European HEIs from 2001 to 2005. Wolszczak-Derlacz [34] showed a positive association between number of departments and efficiency in both of the European and the US public HEIs from 2000 to 2012. Wolszczak-Derlacz [35] revealed that the HEIs' interdisciplinarity (i.e., number of different faculties) had positive effect on productivity change in the European public HEIs from 2000 to 2010. Johnes and Johnes [42] employed SFA to examine the association between cost efficiency and diversity of outputs in the UK HEIs from 2013 to 2014. They found consistent results with [7] that the more specialized HEIs typically performed inefficiently in the UK. Ripoll-Soler and de-Miguel-Molina [36] analyzed the 4 European merger cases, which were characterized with the well complementary among the pre-merger HEIs, and found all of them successfully moved into the Top 100 after the merger. Among others, the merger case of Aalto University in Finland aimed to attract more talented faculty and student to strengthen its competitiveness by the merger.

In terms of missions, Johnes [43] utilized the panel data of the UK from 1996/1997 to 2008/2009 to compare the means of TE estimated using both SFA and DEA of 19 post-merger HEIs with those of pre- and non-merging HEIs. The results revealed that the former colleges of HEIs who had been awarded university status since 2003 and were small and specialist, as well as often lacking a strong research mission had higher TE than pre-1992 traditional universities who offered degree programs across the academic subject spectrum and had an established research mission. However, they had lower TE than post-1992 HEIs who had a balanced portfolio offering degree programs across a range of academic and vocational subjects and a

growing research mission. The authors thus inferred that the different missions both in terms of outputs produced (research, teaching, or third mission) and/or in terms of subject mix may explain the differences in efficiency. Besides, the inference implied the merger which can diversify the missions of HEIs may enhance TE.

Frølich and Stensaker [19] used thematic document analysis of strategic plans and position papers to inquire whether the merger impacts the diversity in mission with the sample of 15 Norwegian HEIs which formed 6 post-merger HEIs in 2016 and 2017. Their results showed that the mergers may not induce the HE to monotonize the mission to academic excellence or social relevance in national system level, rather, they indeed caused diversity of mission in institution level. That is, the mergers may not reduce the inter-HEIs' diversity of missions, nevertheless, they promote the intra-HEIs' diversity of missions. That thus implies mergers may enhance efficiency due to the diversity in missions.

In terms of geographical locations, Varga and Horváth [33] showed the degree of internationalization had a positive effect on the probability of the HEIs patenting. Kempkes and Pohl [23] employed the DEA and Tobit model and found regional GDP per capita had positive effect on efficiency in 72 German public HEIs from 1998 to 2003. Wolszczak-Derlacz [34] revealed a positive association between regional GDP per capita and efficiency in both of the European and the US HEIs. Wolszczak-Derlacz [35] showed that the productivity growth of European HEIs was positively related with regional economy. All of these results implied the merger which made the post-merger HEIs to expand campus to prosperous region may absorb more and diverse funding sources, and together with more excellent staff and faculty, thereby to promote better use of resources and further upgrade PTE.

On the other hand, if the mergers following increased diversity in fields and interdisciplinary integration, in missions, and in geographical locations, then the increased difficulty in management and in teaching and research, such as complexity and high costs in management due to much more department and staff [44], much more diverged missions to disturb administrators and faculty to well time-allocation in their work [45] and so on, may make the post-merger HEIs to use resources poorly and results in PTE degrading.

Bonaccorsi *et al.* [46] used the directional distance function together with nonparametric and robust frontier estimation to verify efficiency in European HEIs from 2005 to 2009 and revealed that the diversity of outputs had statistically significant inverse U-shape effect on efficiency. Ripoll-Soler and de-Miguel-Molina [36] showed that the University of Strasbourg in France, the newly formed HEI via the merger of three universities with clear overlaps in disciplines in 2009, enhanced its ranking into Top 100 from 2005 to 2015, but fell out of the Top 100 after 2016. These results seemed to imply that the benefit of diversity in fields and interdisciplinary integration caused by mergers may not always outdo the costs, especially from the long-term perspective.

Wolszczak-Derlacz and Parteka [21] did not find significant effect of GDP per capita on efficiency. Bonaccorsi and Daraio [47] did not find evidence demonstrated the impact of locations in larger agglomerations on efficiency. Even, Agasisti and Pohl [48] found a reverse result that HEIs in economically backward regions improved efficiency faster than those in economically advantaged regions. Varga and Horváth [33] revealed that region size, agglomeration of regional business services, regional technological output and the development of the regional innovation system had the negative effect on the probability of HEIs' patenting. Wolszczak-Derlacz [35] showed the productivity growth of HEIs in the US degraded with GDP. These results seem to imply the higher economic development, the lower the HEIs' efficiency.

Puusa and Kekäle [49] inquired the case of the University of Eastern Finland (UEF) which was established in 2010 via a merger and concluded that physical distance and cooperation between two HEIs which were geographically separate was challenging. Similarly, Frølich *et al.* [50] argued that it was the consideration of location that led most cases of mergers to seek a geographically close regional partner.

Zeeman and Benneworth [51] based on a review of policy documents and interviews to explore two merger cases in Wales that sought to better compete globally by merging and became so-called 'inadvertent multi-campus universities' after the merger. The study highlighted that mergers in pursuit of globalization may cause HEIs to neglect and reduce the achievement of local missions, such as overlooking local-oriented teaching and research, thereby reducing educational equity and research which were beneficial to regional economic development. Papadimitriou and Johnes [7] revealed that the proportion of total students from overseas had no significant effect on efficiency.

Another possible scenario links merger to PTE is that if a merger is accompanied with specialization in fields, unicity in mission and concentration in geographical locations, then the post-merger HEI could be difficult to attract excellent staff (comprising administrator and faculty) and students. If so, the merger could not promote better use of resources, and thereby the PTE scores after the merger get worse.

The claims from [37, 52] suggested that if a merger was aimed to efficiency-pursuing, then may result in a reduction in duplication of programs across HEIs. That may make the post-merger HEIs out of favor by students due to the imperfect geographical mobility for students.

Fourthly, if the merger can improve bureaucracy, academic identity, cultural identity, affective commitment, or staff stress at the meso (organizational) and micro (individual) levels, then the staff will be inspired and the well morale caused by merger may make the post-merger HEI fully give play to complementation among staff and therefore improve use of resources [24, 25, 26, 53], such as the talent staff of the pre-merger HEIs may help to enhance the use of resources in the post-merger HEIs, and thus will reveal as upgrading efficiency in management

and in teaching and research. If so, a higher PTE score following the merger will show.

Inversely, if a HEI merger causes incoordination in academic identity, cultural identity, and affective commitment, or brings much more stress on staff, then will weaken cohesiveness of the staff. That thereby may worsen use of resources and will show poor ability in management and in teaching and research. If so, a lower PE score following the merger will be revealed.

Nyeu [54] and Cai [55] argued that well-integration on the cultural front could be mostly achieved in 'strong + weak' mergers but in similar academic fields, because the recognition of the possible enhancement in academic profile through the merger made the relatively weaker institution tend to be more in favor of the merger. Since the strong or weak was distinguished by organizational history, size and academic prestige and strength in their studies, the results implied the possible complementary benefit of a merger on post-merger HEI mainly came from well-integrated in culture and mission, and economy of scale rather than from the diversity in fields and interdisciplinary integration.

Puusa and Kekäle [49] revealed the slow and difficult process in organizational identity in the post-merger Finnish HEI. Estermann and Pruvot [9] highlighted that the expected benefits from merger in European HEIs, such as efficiency enhanced by economies of scale and scope, more competitive research profiles, more international collaboration and so on, may not occur, or need long time to display, however, the cultural transfer accompanied with the merger was very difficult for the post-merger HEIs.

Consistently, Safavi and Håkanson [56] inquired the voluntary merger case of two British HEIs, one was a large, research-intensive and internationally recognized university and the other was a smaller, teaching-intensive, and well-acknowledged art college in 2011. The study showed that the administrators, especially the art college ones, were perceived demotivated, disappointed and anxious in the integration process, which was consistent with [57] results from France. Moreover, the change in academic identity resulting from the merger, manifested in the fact that research published in top peer-reviewed journals became the sole focus, rather than actual performance (quality, novelty, or usefulness of new ideas), had made the inter-disciplinary research in practice distinctly incompatible or even hindered.

Russell [38] stated that what the merger exerted on productivity was theoretically blurred due to potential difficulties of reorganization and uncertainty about cost-saving. That was consistent in practice, both of staff and students in the post-merger HEI have perceived the full of challenge and worry in the management, teaching, and research.

Ripoll-Soler and de-Miguel-Molina [36] showed that in the case of the University of Lisbon in Portugal, the post-merger HEI seemed to well tackle the bureaucracy and improve its ranking after the merger. On the other hand, in the case of Aalto University in Finland, the ranking indeed was upgraded after the merger, however, the common

increased bureaucracy among the pre-merger HEIs was detracting from consensus and integration. In the case of the University of Strasbourg in France, although the ranking was upgraded to the Top 100 from 2005 to 2015, it seemed that the increasing resistance in cultural integration, so as to make its ranking out of the Top 100 since 2016.

Johnes and Tsionas [8] found that most mergers showed that it was relatively hard to improve efficiency after the mergers no matter the pre-merger HEIs' consistency in age, culture and focus, size, and geographic location (measured by the distance between/among pre-merger HEIs). They thus claimed that each case of merger was quite distinct, therefore the efficiency consequence following the merger may be disparate with their culture, focus, relative size and geographical location, and even motivation for merger. In light of this, merger should not be a generally available policy to upgrade efficiency for all HEIs.

Both of Fumasoli *et al.* [58] and Ripoll-Soler and de-Miguel-Molina [36] stressed that it was the common culture formed by staff's attitudes and behavior critically determined the merger progress and consequences. The well cultural-integration needed time, and thus it needed the longstanding perspective tracing to get the idea of the effects of the HEI mergers. Moreover, de-Miguel-Molina [36] concluded from the 5 merger cases that the heterogeneity in local and national/international factors needed to be taken into account together to fairly assess what the mergers brought to the post-merger HEIs.

Wollscheid and Røsdal [16] adopted the meta-synthesis approach to review 21 studies of different countries and highlighted that the impact of mergers on HEIs may stem from what they call a micro-level process, namely the change following the merger in staff's cultural identity, academic identity, emotions, and teaching and research. They summarized that mergers were time-consuming, and the disciplinary cultures evidently influenced post-merger micro-level processes. Further, the staff from lower-status HEIs experienced more negatively than that from higher-status HEIs. Policy reforms, such as shifting academic identity from a research orientation to a balanced teaching and research orientation, can indirectly mitigate the negative impact on individuals. In view of this, they called for the need to track and confirm the consequences of the merger from a long-term perspective involving students, staff, and quantitative indicators.

Ursin and Aittola [14] explored four different HEIs' mergers in Finland, three of them have finished merger in 2010, the last one was still in the process though was with highly uncertainty. Their focus was on the implementation phase of the mergers and thus collected data in 2009 by interviews with management, personnel, teachers, and students from each HEI. The interviewees expected and paid attention to the benefit of the mergers more on education rather than research, in addition, they approved that the culture and history in their own HEIs critically determined the effect of the merger on education. Further, there were relatively few educational innovations derived from the mergers until now, that was due to the high cost in the administrative and organizational transformations,

the authors explained. The common culture forming was required and crucially depended on the well-functional management and leadership, together with the well and transparent communication.

Slade *et al.* [59] adopted three rounds of surveys of full-time faculty and regression models to examine the impact of a merger of two very dissimilar HEIs in the University System of Georgia (USG) in the US, one was research-oriented and the other was teaching-oriented, on faculty research productivity from 2013 to 2018. They found that the research productivity in terms of peer-reviewed journal (PRJ) articles in the last five years in the post-merger HEI, Augusta University (AU), continuously declined after the merger. The result demonstrated the diversity in mission caused by the merger obviously brought in the post-merger HEI more costs rather than benefits, due to the undesirable cultural integration, that is, the merger of diverse mission but ill cultural integration brought in the post-merger HEI the undesirable costs, such as the tension between/among the pre-merger HEIs, distraction to staff, and so on, so cannot improve use of resources and thus research productivity. The authors thus suggested that the merger of different missions and thus culture of legacy HEIs should more focus on the culture amalgamation, and called for the administrators and policy-makers who are attempting to enhance research productivity by means of merger to take this example as the alert.

Also, according to the argument of [7, 28, 36, 60, 61], if the merger of HEIs can effectively break down or relieve the organizational inefficiency caused by bureaucracy, it will facilitate the complementary effect among pre-merged institutions, so as to promote the efficient use of resources in the post-merger HEI. Thus, a higher PTE score following the merger should display.

On the contrary, as mentioned by [35, 46], the larger HEIs may be less elastic and more bureaucratic, and therefore inversely impacts productivity growth. In light of this, the merger, which usually will enlarge scale, may not help to effectively dismantle the bureaucracy or even aggravate the bureaucracy due to centralization in the post-merger HEIs, so as to be helpless and even worsen the use of resources and therefore is revealed in the decay in PTE score.

B. The Possible Factors Linking Merger to SE

Besides enhancing PTE through better utilization of resources, the merger may also improve TE by optimizing SE to minimize the newly formed LAC of the post-merger HEI, namely, to cut the LAC given the revenue unchanged or to make proportion increase in revenue greater than that in costs after the merger. That could be fulfilled through economies of scale and scope. Some effects induced by the merger could make the post-merger HEIs benefit from economy of scale, manifested as the decreasing LAC with enlarged scale, so as to improve the SE score after the merger.

Firstly, mergers may cause economies of scale because they may allow the post-merger HEIs to cut costs by eliminating redundant resources even as they grow larger. If this is the case, the post-merger HEIs will show a

decrease in LAC with the increase in size, thus will upgrade the SE score after the merger.

The second, the production states of pre-merger HEIs may impact the LAC after the merger. Indeed, as long as one of the pre-merger HEIs has already produced in the state of decreasing return of scale, the post-merger HEIs will very likely suffer from diseconomy of scale, i.e. DRS, revealed as the increasing in LAC with the increase in size.

The third, diversity in fields and interdisciplinary integration, diversity in missions (i.e., from monotonic academic identity to multiple identities), and diversity in geographical locations (multi-campus, Cross-border HE, or transnational HE (TNHE)) could impact the LAC in the post-merger HEIs. If the increased diversity in fields and interdisciplinary integration, in missions, and in geographical locations, which caused by the merger, make the proportion increase in revenue greater than that in costs, then the benefit of IRS may make the post-merger HEI's LAC lower than that before the merger given the right-shift of LAC, so as to upgrade the SE score after the merger. In this case, since the LAC decreases as the expanding diversity is caused by a merger in the post-merger HEIs, the result also demonstrates the economy of scope derived from the merger. The case may happen since the increased diversity in fields and interdisciplinary integration, in missions, and in geographical locations, which following the merger, make the post-merger HEIs attract more talent faculty and students to gather, thus bring in more tuition income and interdisciplinary research grants and even international cooperation, resulting in a proportion increase in tuition and research revenue greater than that in costs.

Conversely, if the increased diversity in fields and interdisciplinary integration, in missions, and in geographical locations, which caused by the merger, make the proportion increase in revenue lower than that in costs, then the effect of DRS will make the post-merger HEI's LAC higher than that before the merger given the right-shift of LAC, so as to degrade the SE score after the merger. In this case, since the LAC increases as the expanding diversity is caused by a merger in the post-merger HEIs, the result also demonstrates the diseconomy of scope derived from the merger.

Also, if the merger is aimed to promote the macro level (i.e., national system) diversity in fields and interdisciplinary integration, in missions, and in geographical locations, such as the government policy is aimed to make individual HEI more specialized in specified fields, unitary mission, and cluster in the specified region to aid regional economic development, then the meso-level (i.e., organizational level) of diversity in academic fields and interdisciplinarity, missions, geographical locations will tend to monotonic [26, 28]. The post-merger HEI thereby is not available to benefit his SE from economy of scope.

Wolszczak-Derlacz and Parteka [21] found that the numbers of both students and faculties have positive effect on efficiency. In addition, the composition of faculty significantly impacted efficiency, such as the HEIs with medical/pharmacy performed more efficiently. Varga and

Horváth [33] verified that the size and degree of internationalization had positive effect on the probability of the HEIs patenting, whereas the region size, concentration of public research, cluster of regional business services, regional technological output and the development of the regional innovation system had negative effect on the probability of the HEIs patenting. Johnes and Johnes [42] demonstrated the increasing returns to scale and scope in UK HEIs. Wolszczak-Derlacz [34] revealed the number of departments had the positive effect on efficiency in Europe and the US. Wolszczak-Derlacz [35] showed that the size of HEIs had positive effect on productivity, though negative effect on productivity change in either the Europe or the US. In addition, the HEIs' interdisciplinarity (i.e., number of different faculties) had positive effect on productivity in the Europe. All of these results stated above implied the mergers, which enlarge scale or expand diversity in fields and in interdisciplinary integration, may raise SE through the economies of scale and scope.

Ripoll-Soler and de-Miguel-Molina [36] revealed the evidence of economies of scale and scope from four complementary merger cases of HEIs in EU, and shown as the HEIs' ranking upgraded after the different-scaled and complementary merger. Among others, the case of Aalto University in Finland was the merger between one large university (Helsinki University of Technology) and two smaller ones (Helsinki School of Economics and the University of Arts and Design Helsinki) in 2010. The case of Centrale-Supélec was the merger of two specialized and high educational profile institutions in France in 2015. The case of University of Lisbon was the merger of the University of Lisbon and the Technical University of Lisbon in Portugal in 2013. The merger motivated to improve his research rank by expanding scale, as well as diversifying disciplines and indeed had accessed expected achievement after the merger. The case of University of Manchester was the merger of the small, highly specialized university, the University of Manchester Institute of Science and Technology (UMIST) and the large comprehensive university, Victoria University of Manchester (VUM) in the UK in 2004. In addition, the authors claimed that the HI still produced at the optimal scale following the merger.

Chen [1] performed the DEA to investigate two cases of HEIs' mergers in Taiwan from 2012 to 2017 and revealed that the NPTU optimized scale and thus his SE after the merger, though due to the scale had been optimized before the merger except 2014, the results apparently needed to be further traced and then be verified.

However, the economies of scale and scope may be revealed conditionally. In terms of economy of scale, Yuan *et al.* [62] found evidence from China and demonstrated the merger between HEIs with similar size had negative effect on patent applications after the merger. Liu *et al.* [63] designed multiple regression models to verify the impact of mergers on the HEIs' research performance, which was measured by the production of scholarly publications, with the sample set of 29 Chinese and 8 Nordic HEIs' mergers from 2000 to 2010. They revealed that in China, the HEIs'

mergers had a small but significantly positive effect on publication growth rates, however, this only was for mergers of non-Project 985 universities and the mergers of a comprehensive university and a medical school. In addition, they showed the benefit from the merger on research productivity was only found in the mergers between a large comprehensive university and much smaller universities rather than in those between similarly sized universities. On the other hand, the evidence demonstrated the benefit of mergers on research performance in Nordic universities was weak and lack of consistency. They speculated their results were due to the difficulties to eliminate redundancies and to well integrated make mergers between universities of similar size bring limited benefits and more cost over benefit, that therefore revealed the non-significant increase in publication growth rate after the mergers. The results demonstrated the benefit of mergers from the economies of scale in terms of research performance under some given conditions, such as quite divergent scale, in Chinese HEIs' mergers, nevertheless, the benefit may be weak and inconsistent in Nordic ones.

In terms of economy of scope, Kyvik and Stensaker [41] argued that the horizontal mergers between HEIs with highly similar academic fields suffered from higher difficulties to well integrate after the merger. Conversely, the vertical mergers between HEIs with more diverse academic fields and stronger support services, made more choices for students and an increased capacity for organizational flexibility and international competitiveness. Their results suggested the merger accompanied with increased diversity in fields and in interdisciplinary integration may derive more benefits than costs and thus may enhance scale efficiency by the economy of scope. Additionally, the merger benefited SE by economy of scope rather than by economy of scale. Consistently, Papadimitriou and Johnes [7] found a negative effect of size on efficiency together with the improvement of efficiency after the merger simultaneously, and they hence inferred that the merger may benefit HEIs' efficiency typically by economy of scope rather than by economy of scale. That was consistent with [3] inference. Finally, Johnes's [43] result implied the mergers which can diversify missions of the HEIs may boost efficiency through the economy of scope.

Furthermore, the nonlinear effect of scale and scope on efficiency had been shown. Bonaccorsi *et al.* [46] revealed both of size and scope have statistically significant inverse U-shape effect on efficiency in European HEIs from 2005 to 2009. Johnes and Tsionas [8] found HEIs with greater proportion of honors degree graduates have higher inefficiency. They explain that this was due to the resource-intensive nature of quality education output, which leads to increased inefficiency. Further, they showed that the tendency to merge was not significantly affected by inefficiency, that means, HEIs engaged in mergers may be neither necessarily poor performers nor necessarily aimed to seek efficiency upgrades. Moreover, they found that the size of HEIs had positive though nonlinear effect on both of inefficiency and tendency to merger, respectively. Take

these results together, their results seemed to demonstrate that the HEIs engaged the mergers typically seek to remove the inefficiency caused by the diseconomy of scale rather than the inefficiency caused by poor management or faculty. Finally, the study revealed that the efficiency upgrade appeared just at the beginning and then disappeared soon following the merger. In addition, most mergers showed the low probabilities to improve efficiency no matter the pre-merger HEIs' consistency in age, culture and focus, size, and geographic location (measured by the distance between/among pre-merger HEIs).

Bonaccorsi and Daraio [47] employed the Pearson correlation coefficient analysis and Geographical Agglomeration Index (GAI) to explore the size and agglomeration effects (or named cluster effects) on Italian and French public research productivity in 1997. The study found the association between size and efficiency varies across disciplines. Their evidence did not demonstrate the economy of scale, and even showed evidence of diseconomy of scale (i.e., DRS) in some disciplines.

Ripoll-Soler and de-Miguel-Molina [36] found the ambiguous evidence from the case of University of Strasbourg in France, which was the merger of three universities with clear overlaps in disciplines in 2009. His ranking upgraded into the Top 100 from 2005 to 2015, though out of the Top 100 since 2016. The authors explained it seemed that the increasing resistance in cultural integration made the ranking decay, further, he also stated that that the HEI had been too large relative to those in the top 100 after the merger. Taking together, the study results implied the possible DRS in this case.

Chen [1] found that the voluntary merger case of NTHU in Taiwan experienced the decay of TE resulting from the deterioration in both of PTE and SE after the merger. That thus demonstrated the merger caused diseconomies of scale and scope, though the apparent diversity in mission, fields and disciplines, and scale between the two pre-merger HEIs. However, limited by the data available due to the merger was fulfilled in 2017, and thus only one-year data is available to be examined, obviously the results needed to be further traced and verified. Slade *et al.* [59] showed that the research productivity in the post-merger HEI, Augusta University (AU), continuously decayed after the merger. The result verified the diversity in mission caused by the merger brought in the post-merger HEI more costs than benefits, and therefore the diseconomies of scale and scope.

In sum, as highlighted by [7, 8, 11–16, 36, 63], the worldwide evidence demonstrated the merger in HEIs was complex and expensive in cost and time, the consequence may vary with sources of funding, willingness, size, disciplines and academic fields, geographic location, as well as meso-level and micro level of cultural, mission, emotions and perceptions and macro conditions, such as government policy, stage of economic development. Therefore, each case of merger needs to be viewed case by case, and traced and verified in longstanding to access the whole picture and to provide optimal guideline to administrators, faculty, and policy-makers.

Furthermore, Johnes [17] argued that the disregard of managerial inefficiency will make biased and inconsistent estimates and subsequent inferences, Andrews *et al.* [64], Schiltz and De Witte [18], Zhang and Worthington [10] emphasized that sufficient agility in specifying functional form is necessary to ensure the robustness of the estimated results. Additionally, Zhang and Worthington [10] had shown that the quadratic cost functions used in some studies have a significant inverse effect on the scale economies, they thus concluded the choice of functional form is not neutral in the estimation of efficiency.

To sum up, in view of the divergent empirical results in the past literature due to the use of different functions and estimation methods, this study thus applies case studies and a nonparametric estimation method of DEA, which is free from function form setting and is allowed to explore the causes of inefficiency, to examine the effect of HEIs merger in Taiwan on their technical efficiency, pure technical efficiency and scale efficiency from 2012 to 2020.

III. METHODOLOGY AND DATA

A. Methodology and Data

In light of the emphasis on the necessity of flexible methodology to take inefficiency into account and to avert method misspecification bias from previous studies, this study employed the nonparametric method of DEA to assess the impacts of HEIs' merger on their efficiency, as well as to clarify the channels through that the merger influence the HEIs' efficiency.

DEA is a nonparametric analysis method without functional form presupposition, derived from the efficiency measurement method of [65]. The method applies linear programming to seek the efficiency frontier of overall samples, and then compares with individual production point to assess relative efficiency score of each producer. Charnes *et al.* [66] developed DEA conditional on the input-oriented and Constant Returns to Scale (CRS) and was so-called CCR model. Banker *et al.* [67] further extended the method to relax the original assumption of CRS in CCR model so that the model could be estimated in the condition of Variable Returns to Scale (VRS), resulting in the so-called BCC model. Taking the CCR and BCC models together, the DEA is allowed to further investigate whether the main cause of technical inefficiency is pure technical inefficiency or scale inefficiency. The former reveals the inefficiency is caused by the poor use of resources, whereas the latter presents that the inefficiency is caused by the producer's failure to optimize his scale to reach the production point of minimum cost. The CCR and BCC models are detailed as follows, respectively.

1) CCR model

Charnes *et al.* [66] extended efficiency measurement to multiple production practices with mathematical programming method and assumed that all decision-making unit are CRS, namely, assumed that all of them produced at the state of optimal scale and overlooked the

inefficiency caused by diseconomies of scale. The CCR model is presented as follows:

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

$$\text{s.t. } Y^{\text{Overall}} \rho > Y_j \quad (2)$$

$$X^{\text{Overall}} \rho \leq \theta_j X_j \quad (3)$$

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

where, θ_j : the percentage of cuts the j^{th} HEI needs to make in order to be efficient, ρ : $N \times 1$ vector of each HEI weight forming efficient frontier, Y^{Overall} : $B \times N$ matrix of B types of outputs for overall HEIs, X^{Overall} : $A \times N$ matrix of A types of inputs for overall HEIs, Y_j : $B \times 1$ matrix of B types of outputs for the j^{th} HEI, X_j : $A \times 1$ matrix of A types of inputs for the j^{th} HEI, θ_j is the efficiency score for the j^{th} HEI and a value of 1 indicates that the HEI is technically efficient.

2) BCC model

Banker *et al.* [67] further take potential scale diseconomies into account, which is namely BCC model. The linear programming problem of BCC model is defined as follows:

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

$$\text{s.t. } Y^{\text{Overall}} \rho > Y_j \quad (6)$$

$$X^{\text{Overall}} \rho \leq \theta_j X_j \quad (7)$$

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

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

where, θ_j : the percentage of cuts the j^{th} HEI needs to make in order to be efficient, ρ : $N \times 1$ vector of each HEI weight forming efficient frontier, Y^{Overall} : $B \times N$ matrix of B types of outputs for overall HEIs, X^{Overall} : $A \times N$ matrix of A types of inputs for overall HEIs, Y_j : $B \times 1$ matrix of B types of outputs for the j^{th} HEI, X_j : $A \times 1$ matrix of A types of inputs for the j^{th} HEI, N : $N \times 1$ vector of ones.

The individual HEI's efficiency scores estimated by CCR model presents the individual HEI's level of technical efficiency (TE) relative to the efficiency frontier which is derived from overall HEIs, and the individual HEI's efficiency scores estimated by BCC model is the individual HEI's level of pure technical efficiency (PTE). Banker *et al.* [67] showed that the TE is the product of pure technical efficiency and Scale Efficiency (SE), namely:

$$\text{TE} = \text{PTE} \times \text{SE} \quad (10)$$

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

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

The individual HEI's efficiency score ranges from 0 to 1. If an HEI has achieved technical efficiency, it should be

shown that his technical efficiency score, pure technical efficiency score and scale efficiency score are all equal to 1, i.e., $\text{TE} = 1$, $\text{PTE} = 1$, and $\text{SE} = 1$; Otherwise, if the HEI fails to achieve technical efficiency, i.e., $\text{TE} < 1$, the model is allowed to further examine whether technical inefficiency is mainly caused by pure technical inefficiency or scale inefficiency. If the HEI has a $\text{PTE} < 1$, it indicates that the HEI is pure technical inefficient, he thus should focus on improving the efficiency of resource use by enhancing his ability in management and in teaching and research, so as to effectively upgrade the PTE. That means, only the merger, which can indeed do his favor to improve the use of resources, could upgrade the PTE and thus TE following the merger. On the other hand, if a HEI has a $\text{SE} < 1$, it reveals that the HEI is scale inefficient, that is, the HEI cannot minimize its costs due to the deviation from optimal scale. The SE can be upgraded by further cost-cutting given the revenue unchanged or by making the proportion increases in revenue greater than that in cost, i.e. IRS. Thereby, the merger which is with economy of scale and scope can be helpful to do this. The merger does enlarge scale, though merger is not necessary to upgrade SE and thus TE if the expected benefit on economies of scale and/or scope does not happen.

Since merger usually enlarges the scale of post-merger HEIs, that implies the LACC shift to right after the merger. Given this, this study is allowed to compare PTE scores before and after the merger to clarify whether the merger improves the ability in management and in teaching and research. That is, if the PTE score in post-merger HEI is higher than that in pre-merger HEIs, then that reveals that LACC shifts to right, and the merger enhances efficiency in management and in teaching and research by improving the use of resources.

In the same way, if the SE score in post-merger HEI is higher than that in pre-merger HEIs, and equal to 1, that reveals that LACC shifts to right, and the post-merger HEI's product is at the scale of minimized LAC, namely, at the state of CRS. That presents the proportion increase in revenues is equal to that in costs after the merger.

If the SE score is upgraded but lower than 1 after the merger, that presents that LACC shift to right after the merger, and the post-merger HEI's LAC is lower than that before the merger compared with the efficiency frontier. In this case, the post-merger HEI may be produced in the state of IRS or DRS. If it is IRS means after the merger the proportion increase in revenues is greater than that in costs. The post-merger HEI can minimize cost by further enlarging scale. On the contrary, a production state of DRS means after the merger the proportion increase in revenues is lower than that in costs. That is, the post-merger HEI is not only already too large to further minimize cost by scaling up, but increasing cost when further expanding scale. On the other hand, if the SE score declines after the merger, that verifies that after the merger, LACC shifts to right, but the production state is not at the scale of minimized LAC compared with the efficiency frontier. In this case, it implies the post-merger HEI may be produced in the state of IRS or DRS.

A higher SE score may also be derived from the economy of scope caused by the merger. The economy of scope means the LAC is decreasing with a variety of products. Namely, it is shown that the post-merger HEI's LAC is decreasing with more academic fields and interdisciplinarity, missions (i.e., from monotonic academic identity to multiple identities), or geographic locations (and thus more teaching and research activities across regions and even countries) after the merger. The post-merger HEI benefits from economies of scope has lower LAC because costs are spread over a variety of products. This is since a more diverse HEI which has more colleges, departments, disciplines, courses, and multi-campus may not only expand sources of tuition and research income due to the diversity of the department and courses, such as tuition and research income from expanding fields and even from overseas students and international cooperation, but also expand the total amount of tuition income and research, such as to promote the willingness of domestic parents and students to choose the school, thereby increasing the general tuition income, and to accelerate more domestic industrial cooperation to raise research income. If so, the expanded revenue should be greater than the expanded cost after merger, and an IRS or CRS after the merger should show. On the contrary, if a DRS is found, the result implies that the inefficiency and complexity of the merger add more cost burden and even exceed its benefit to the post-merger HEI, and therefore deteriorates the SE and thus the TE.

If the merger creates more diversity in HEIs' fields and interdisciplinary integration, or in missions, or in geographic locations, and makes the proportion increase in revenues greater than that in costs, thereby makes a lower LAC after the merger than that before the merger compared with the efficiency frontier, then a higher SE score will also show. If so, the study will demonstrate the LAC is decreasing with more fields, interdisciplinarity, missions, or geographic locations after the merger, namely, the so-called economy of scope. That is, the study will demonstrate the merger enhances SE by economy of scope.

In contrast, if the merger makes more diversity in fields and interdisciplinary integration, or in mission, or in geographic locations, but makes the proportion increase in revenues lower than that in costs, thereby making a higher LAC, then a lower SE score will show. If so, the study will reveal the LAC is increasing with more fields, interdisciplinarity, mission, or geographic locations after the merger, namely, the so-called diseconomy of scope. That is, the study will demonstrate the merger lowers SE score by diseconomy of scope.

To sum up, HEIs' merger is complex and costly, neither a panacea nor one size fits all. It is crucial to get the whole picture of the merger from the long-run perspective and that is what this study purposed to fulfill and why this study adopted DEA.

In terms of output and input measures, this study proposes that outputs and inputs should be measured by the ones which are as close as possible to the practical state of resource sources and use in the current Taiwanese HEIs. In light of this, this study measures outputs and inputs

primarily based on the 'National University Endowment Fund Establishment Act' [68] in Taiwan, and together on the practical income and expenditure status shown in the financial statements of HEIs, so that the HEI's output and input measures in line with the practical operation situation are defined.

Since 1999, to respond accordingly to HE development trends, enhance the performance in education and research, and facilitate the financial flexibility of HEIs, Taiwan's Ministry of Education passed and implemented 'National University Endowment Fund Establishment Act'. The Article 1 of the Act regulates national university and tertiary college shall establish a university endowment fund. Moreover, the legal sources of funding and use for a public university endowment fund are specified in Articles 3 and 4. Article 3 specifies, besides government normal budget appropriations, there are some self-raised income of the following nature: 1) Income from tuition and fees, 2) Income from continuing education, 3) Income from academia-industry cooperation, 4) Income from government subsidies for scientific research or from government commissions, 5) Site facility management income, 6) Donation income, 7) Investment income, 8) other income. Article 4 further regulates that a university endowment fund is to be used for the following: 1) Teaching and research payments, 2) Personnel expense payments, 3) Student scholarship and grant payments, 4) Continuing education payments, 5) Academia-industry cooperation payments, 6) Asset and property addition, expansion, and improvement related payments, 7) Other university development related payments. Under this Act, the funding sources and uses of public HEIs have been liberalized, so compared with private ones, there are no tighter limitations on the outputs and inputs of public HEIs. However, all public HEIs' financial statements show that due to the lack of driving, such as fine system of rewards and penalties, almost all of them are very conservative in the management of endowment funds. Thereby, government budgets and tuition fees have long been the two main sources of income for Taiwan's universities and colleges.

In light of this, to be in line with the practical operation situation, taking the Act and practical financial statements into account together is required, this study hence adopts income from tuition and other fees, income from academia-industry cooperation and government subsidies for scientific research or from government commissions as two output measures, and teaching and research payments, academia-industry cooperation payments, administration and general expenses, and net fixed assets, which is fixed assets minus accumulated depreciation, as four input measures.

B. Three Cases of Merged HEIs

There are three cases of merger in this study, and are introduced as follows.

National Pingtung University (NPTU) was established via the merger of two similar size and diverse in fields HEIs, National Pingtung University of Education (NPUE), which mainly consisted of schools of education, art and science, and the National Pingtung Institute of Commerce

(NPIC), which was mainly a business school, on August 1, 2014. The post-merger HEI has become a comprehensive university of normal education, management, computer, science and technology, and HE in Pingtung City. By now, the post-merger HEI has 3 campuses in Pingtung City [69].

National Tsing Hua University (NTHU) is a prestigious university with a long history. As early as in 1911, Tsing Hua Academy was founded at Tsing Hua Garden in Beijing, China. In 1928, it was renamed as NTHU. In 1956, NTHU was rebuilt in Hsinchu, Taiwan. Since then, NTHU has transformed from a research institution focusing on nuclear science and technology to a comprehensive research university comprising science, engineering, humanities, society, and technology management. On November 1, 2016, NTHU formally merged with National Hsinchu University of Education (NHCUE), which was a much smaller HEI relative to NTHU and mainly consisted of schools of education, art, and science. NTHU has long been one of Taiwan’s top universities and has been perceived as the best incubator for future industry leaders and scholars, after the merger, he has further expanded to fields of education and arts. By now, the post-merger HEI has 2 campuses in Hsinchu City [70].

National Kaohsiung University of Science and Technology (NKUST) has been the largest technological university in Taiwan after the merger of three universities: National Kaohsiung University of Applied Sciences (NKUAS), National Kaohsiung First University of Science and Technology (NKFUST), and National Kaohsiung Marine University (NKMU) on February 1, 2018. Among the pre-merger HEIs, MKUAS was relatively large, while NKFUST and NKMU were of comparable size. After the merger, NKUST mainly overlapped in fields of business, science and engineering derived from MKUAS and NKFUST, though has expanded to marine management and technology due to the entry of NKMU. Since the merger, NKUST has integrated the strengths of the three pre-merger HEIs, namely, the strong connections with industries, innovation and entrepreneurship, and ocean technology to develop to a technological university comprising electrical engineering, computer science, hydrosphere science, marine and marine commerce, humanities, society, and management. By now, the post-merger HEI has 5 campuses in Kaohsiung City [71].

Following [3, 72], this study considers the potential impact of inter-HEI heterogeneity on resource and input-output mix and thus may cause estimation bias, so for the cases of NPTU and NTHU, 46 comprehensive HEIs and 7 technical HEIs were included to estimate the efficiency frontier. That was since the merger cases of the two HEIs are mergers of educational HEIs and comprehensive HEIs, in order to verify the effect of post-merger on efficiency, 7 educational universities need to be comprised in the sample. Therefore, this study comprised 53 comprehensive and educational HEIs from 2012 to 2016 and 52 comprehensive and educational HEIs from 2017 to 2020 as sample to estimate the efficiency frontier yearly. As for the NKUST case, since his three pre-merger HEIs were all technical HEIs, this study estimated the efficiency frontier

with 73 technical HEIs from 2012 to 2017, and 63 technical HEIs from 2018 to 2020. That was because this study excluded 8 technical HEIs, which have failed to operate in recent years and thus have not completely disclosed their financial statements over the sample period in this study. Table I describes the main sample statistics.

TABLE I. SAMPLE STATISTICS DESCRIPTION (UNIT: NT\$ MILLION)

Statistics	Income from tuition and fees	Income from research output	Teaching and research payments	Academia-industry cooperation payments	Administration and general expenses	Net fixed assets
Comprehensive and educational HEIs from 2012 to 2020						
Mean	795	625	1451	586	307	4943
Standard deviation	571	1079	1179	1054	241	4506
Maximum	2465	7084	7680	6983	1731	38341
Minimum	8	1	25	4	43	552
Technical HEIs from 2012 to 2020						
Mean	592	114	716	104	167	2270
Standard deviation	344	173	414	161	79	1402
Maximum	1663	1068	3587	1008	578	8103
Minimum	23	3	120	3	35	503

IV. EMPIRICAL RESULTS

A. Impacts of Merger on Efficiency-NPTU Analyses

DEA efficiency scores of NPUE and NPTU from 2012 to 2020 are displayed in Table II. As shown in Table II, in the pre-merger period, NPUE was all the time an efficiency university ($TE = 1$) due to its well-performed management as well as teaching and research ($PTE = 1$) together with optimal scale ($SE = 1$) from 2012 to 2013. However, in 2014, NPUE became inefficient due to the decrease in SE ($SE=0.96$) caused by IRS. After the merger and to be NPTU, the new university again restored to be an efficient university until 2018. That was caused by he still performed well in management and in teaching and research ($PE = 1$). In addition, he regained his SE to be optimal scale again ($SE = 1$) after the merger.

However, the benefit due to the merger did not last too long, in the following two years, NPTU again became an inefficient university due to falling SE, and went from bad to worse. In 2019 and 2020, i.e., the fifth and sixth years after the merger, NPTU’s SE were 0.933 and 0.927, respectively, even lower than that in the pre-merger year of 2014, 0.96. This directly resulted in a mean of SE of 0.977 after the merger, which was lower than 0.987 before the merger. Since the states of production were still in the IRS in 2019 and 2020, the lower SE indicated that the post-merger HEIs should further minimize their LAC by scaling up their outputs. Since the merger engaged in diversity in fields and in interdisciplinarity, and multi-campus, the results also suggested NPTU should well take the advantage of multi-field, interdisciplinarity and multi-campus to struggle to innovate more and diverse courses, programs and research that meet the needs of the times, so as to attract more students, more local public-funding schemes, more public-private collaboration schemes, more industry-academy cooperation projects, and even

international industry-academy cooperation projects. By doing so, both of tuition revenue and research funding could vividly increase and thus boost his SE. All in all, the results have fully demonstrated that the merger did not obtund the shock of declining fertility on HEIs, rather made the post-merger HEI to be further in the pickle, even for a HEI which was efficient in management and in teaching and research.

The results seemed to confirm that merger of HEIs was helpful to optimize scale, namely, to minimize LAC further. Besides, since the merger indeed enlarged scale and also expanded diversity in fields and interdisciplinarity, the results demonstrated the economies of scale and scope following the merger, namely, the LAC decreased with the increased scale and diversity of production. The results about economies of scale and scope were consistent with [21, 33–35, 42, 61], while with [7] agreed only on the economy of scope. In addition, since the NPTU established by two HEIs with equivalent size, the results were discrepant with the findings of [62] and [63], both of them revealed the mergers between HEIs with

similar scales in China had negative effect on research performance after the merger.

Moreover, the no lasting benefit and even deteriorative effect of merger on SE and TE seemed to be more consistent with evidence from China [4, 5], evidence from England [6–8], and evidence from France [36]. Almost all of them found that the positive effect of merger on efficiency was only in the first year, and then reversed to degrade the efficiency. In addition, the results of diseconomies of scale and scope in 2019 and 2020 were consistent with [1–3, 59], while accorded with [7] only in the negative effect of size on efficiency. Also, the results were consistent with [3] in demonstrating the declining fertility rate struck HEIs rapidly and severely in Taiwan, and the mergers could not be the panacea for higher education crisis. Even, this may bring more dilemmas, even for a HEI which was efficiency in management and in teaching and research. Finally, in terms of PTE, the results coincided with [1, 3, 7] in their claim that only efficiency HEIs will better or maintain post-merger HEIs' efficiency.

TABLE II. DEA EFFICIENCY SCORES OF NPTU FROM 2012 TO 2020

53 Comprehensive HEIs Efficiency Frontier												
HEI	TE/PTE/SE	2012	2013	2014	2015	2016	2017	2018	2019	2020	Pre-Merger Mean	Post-Merger Mean
NPUE	TE	1	1	0.960							0.987	
	PTE	1	1	1							1	
	SE	1	1	0.960							0.987	
				IRS								
NPTU	TE				1	1	1	1	0.933	0.927		0.977
	PTE				1	1	1	1	1	1		1
	SE				1	1	1	1	0.933	0.927		0.977
									IRS	IRS		

B. Impacts of Merger on Efficiency-NTHU Analyses

DEA efficiency scores of NHCUE and NTHU from 2012 to 2020 are displayed in Table III. As shown in Table III, before the merger, as a pre-merger HEI, NHCUE suffered from poor and continually declining TE (with a mean of 0.764), mainly due to the continuous downward SE (with a mean of 0.841) caused by the production state of IRS from 2012 to 2016. Conversely, quite differently, NTHU as a survived HEI, its poor TE (with a mean of 0.885) mainly caused by weak PTE (with a mean of 0.892), and in most years his poor SE (with a mean of 0.992) was due to the production state of DRS rather than IRS. The results have implied the inefficiency NTHU which performed poorly in management and in teaching and research actually may be not suitable to merge, as stressed by [3, 7]. Besides, NTHU has produced in the state of DRS, implying the HEI may be difficult to optimize its scale efficiency by further enlarging size, that was, NTHU could not minimize its LAC by means of the merger. However, since NHCUE's PTE was higher than that of NTHU, it was worth expecting a better performance after the merger. Unfortunately, the expectation was not supported by results after the merger.

After the merger, the post-merger HEI, NTHU's TE decayed due to the depravation in both of PTE and SE. For

NHCUE, although TE improved due to the improvement of SE, PTE became much worse. Until 2020, his PTE was 0.876 and was still lower than the level in 2016 the year before the merger, 0.999, even lower than the mean of PTE before the merger, 0.912. That led to NHCUE's means of TE, PTE, SE were 0.764, 0.912, and 0.841 before the merger, and 0.860, 0.873, and 0.986 after the merger, respectively. Namely, the merger made his PTE severely declined and turned his production state from IRS into DRS, though relative scores of SE and TE upgraded. At the same time, for NTHU, his TE was even worse due to both of deterioration of PTE and SE. In 2020, NTHU's of TE, PTE, SE were 0.842, 0.876, and 0.961, respectively, and were still lower than the level in 2016, i.e., the year before merger, 0.932, 0.933, and 0.999, respectively. In terms of mean, NTHU's means of TE, PTE, and SE after the merger (0.860, 0.873, and 0.986, respectively) were all lower than those before the merger (0.885, 0.892, and 0.992, respectively). Namely, the merger made NTHU worse in both of PTE and SE, and resulted in his poor TE. Moreover, even after the merger, it was still mainly his poor PTE, more than poor SE, deteriorated his TE. Finally, it was worth noting that after the merger, SE of NTHU was decreasing yearly, and was sill all in the production state of DRS except to 2018. That implied the post-merger HEI has been too large to minimize his LAC, namely, NTHU

should not only struggle to better his use of resources in order to boost his PTE, but also need to shrink his scale or better his mix of outputs in order to boost his SE by economies of scale or scope, and then his TE can be promoted.

Consistently, the results verified [3, 7] in their claims that only efficiency HEIs will better or maintain post-merger HEIs' efficiency after merger. Furthermore, since the NTHU has long been the so-called top university highly funded by 'Aim for the Top University Project' in Taiwan, the deterioration of PTE and TE after the merger seemed to agree with the findings from [21, 30, 34, 35], namely, in the context lacked of competitive pressure, the higher the public-funding, the worse use of resources, and the lower efficiency.

Moreover, since the merger indeed expanded the diversity in fields and interdisciplinarity, in mission (before the merger, NTHU was research-oriented HEI, though NHCUE was teaching-oriented HEI), and generated multi-campus HEI, the depravation in both of PTE and SE after the merger revealed that the merger could not aid in the better use of resources performed by more talent staff and students gathering together, nor optimizing scale through economies of scale and scope. Besides the lack of good ability in management and in teaching and research in the pre-merger HEIs, the high public-funding though low comparative pressure context, the deterioration of PTE after the merger may be also due

to following the merger, the complexity and high costs in management due to much more department and staff [44], or much more diverged missions to disturb administrators and faculty to well time-allocation in their work [45], or the geographic separation [49–51], or due to the alleviated competitive pressure due to higher market share [37], or due to the still ill-integration in culture identity, academic identity, affective commitment and so on [14, 16, 36, 58, 59]. These still need to be further verified in future research. On the other hand, the deterioration of SE, in this case, revealed the merger derived the diseconomies of scale and scope, was consistent with [1–3, 59], and was consistent with [7] in the negative effect of size on efficiency. Also, the result may be consistent with [8] proposition that HEIs were resources-intensive, therefore there was the trade-off between quality and efficiency. Finally, the results of diseconomies of scale did not agree with the Chinese evidence [63] since they revealed the economy of scale following the mergers of two unlike-sized HEIs.

All in all, the results showed that the merger of NTHU not only failed to optimize HEIs' management efficiency, but also turned HEIs into DRS, and thus the results evidently demonstrated that the merger of HEIs did not aid in improving operational efficiency, let alone solving Taiwan's higher education crisis, or enhancing competition in terms of efficiency.

TABLE III. DEA EFFICIENCY SCORES OF NTHU FROM 2012 TO 2020

53 Comprehensive HEIs Efficiency Frontier												
HEI	TE/PTE/SE	2012	2013	2014	2015	2016	2017	2018	2019	2020	Pre-Merger Mean	Post-Merger Mean
NHCUE	TE	0.854	0.785	0.697	0.759	0.725					0.764	
	PTE	0.906	0.867	0.829	0.958	0.999					0.912	
	SE	0.942	0.906	0.841	0.792	0.726					0.841	
NTHU	IRS	IRS	IRS	IRS	IRS	IRS						
	TE	0.918	0.782	0.833	0.960	0.932	0.872	0.857	0.870	0.842	0.885	0.860
	PTE	0.940	0.790	0.833	0.963	0.933	0.875	0.858	0.881	0.876	0.892	0.873
	SE	0.976	0.990	1	0.997	0.999	0.997	0.998	0.987	0.961	0.992	0.986
	DRS	DRS	DRS	IRS	DRS	DRS	DRS	IRS	DRS	DRS		

C. The Impacts of Merger on Efficiency-NKUST Analyses

DEA efficiency scores of NKUST and its three pre-merger HEIs, NKFUST, NKUAS, NKMU, from 2012 to 2020 are displayed in Table IV. As shown in Table IV, before the merger, all of the three pre-merger HEIs were inefficient and had lower PTE than SE in most years before the merger. This revealed that their inefficiencies were all majorly due to defective PTE. Besides, all of them improved their SE from 0.944, 0.945, and 0.853 in 2012 to 0.991, 0.998, and 0.961 in 2017. And, all of them improved their PTE from 0.844 and 0.84 in 2012 to 0.897 and 0.955 in 2017, except to NKUAS, the relatively larger one, his PTE fell from 0.873 in 2012 to 0.823 in 2017. Therefore, in 2017, the year before the merger, the three HEIs with the highest TE, PTE, and SE were NKMU, NKMU, and NKUAS, respectively. In addition, the three HEIs with the highest pre-merger mean of TE, PTE, and SE are NKFUST

(TE = 0.821), NKMU (PTE = 0.888), NKFUST (SE = 0.969), respectively.

After the merger, the newly formed HEI, NKUST's PTE was efficient in all three years (PTE = 1), though his TE mainly decayed with the scale inefficiency. NKUST's SE in all three years after the merger were lower than SE of the three pre-merger HEIs in individual year and the means before the merger.

For NKFUST, its PTE was raised to 1.0, nevertheless, its TE dropped by severely decreasing SE, and even its production state turned from IRS to DRS. The dramatically enhanced PTE caused a higher post-merger mean of TE, from 0.821 to 0.827. But if we look at the efficiency scores and trends year by year, we found that, in 2018, the first year after the merger, NKFUST's TE fell from 0.889 in 2017 to 0.845 due to a sharp and continued decline in SE, from 0.991 to 0.845, and even worse in 2020, NKFUST's TE fell to 0.819 due to a lower SE of 0.819. That is, until

2020, both of his SE and TE did not recover to pre-merger levels.

Similarly, for NKUAS, its PTE was improved to 1.0, while its TE still fell due to the decline in SE caused by the production state of DRS. Although the substantial improvement in PTE resulted in a higher mean of TE, from 0.749 to 0.827, the yearly levels and trends of the efficiency scores showed that the benefit of merger in TE was only in the first year after the merger, i.e., only in 2018. NKUAS's TE upgraded from 0.822 in 2017 to 0.845 in 2018 since his PTE upgraded from 0.823 to 1.0, and then his TE declined again over the next two years, and never recovered to pre-merger levels by 2020. This was caused by the sharp drop of SE since 2018, from 0.998 in 2017 to 0.845 in 2018 and even to 0.819 in 2020.

Consistently, for NKMU, the sharply enhanced PTE caused a higher post-merger mean of TE, from 0.811 to 0.827. However, the yearly levels and trends showed that the effects of enhanced PTE on TE were cancelled out by dramatic decline in SE. NKMUT's TE fell from 0.918 in 2017 to 0.845 in 2018 due to the sharp drop of SE from 0.961 to 0.845, and even worsened in 2020. In 2020, NKFUST's TE further fell to 0.819 due to the drastic drop of SE to 0.819. Namely, until 2020, both of his SE and TE did not recover to pre-merger levels.

To sum up, after the merger, the PE enhanced to 1.0 and persisted to 2020, which demonstrated that the merger indeed improved the efficiency in management and teaching and research for the three pre-merger HEIs. The results were consistent with [6, 36, 39, 40] in that voluntary mergers aid in better use of resources and thus boost efficiency. Besides, since this merger was characterized by the diversity in fields and interdisciplinarity and multi-campus, the achieving of PTE (i.e., PTE = 1) may be derived from that more outstanding staff and students gathered to the post-merger HEI and thereby better use of resources in management and in teaching and research and hence gained more tuition revenue and research funding, that was uniform with the European evidence revealed by [21, 36], the Norwegian evidence shown by [19, 41], the

UK evidence shown by [7, 42], and the European and the US evidence revealed by [34, 35].

However, the SE of the three HEIs were seriously degraded and their production states were from the IRS to DRS. The results demonstrated the merger of the three HEIs caused the proportion increase in costs was greater than that in revenue, and thus resulted in the state of DRS. Since NKUST was established via the merger of a larger HEI and two of comparable scale HEIs, in addition, NKFUST and NKUAS had more overlaps in fields and faculties, while the entry of NKMU expanded the diversity in fields and interdisciplinarity, the results demonstrated the mixed effect was diseconomy of scale and scope following the merger. The results suggested NKUST should struggle to downsize or to make its proportion increase in revenue greater than that in costs in order to optimize its scale and minimize its LAC, thus boosting its SE. That may be fulfilled by preferably taking advantage of multi-field, interdisciplinarity and multi-campus to struggle to develop more and diverse courses, programs and research that meet the needs of the times, so as to attract more students, more local public-funding, more public-private collaboration schemes, more industry-academy cooperation projects, and even international industry-academy cooperation projects. By doing so, the proportion increase in both of tuition revenue and research funding may be greater than that in cost, and thereby may boost his SE by economy of scope. Though, in the current state of the severely declining fertility worldwide, especially in Taiwan, the increase of tuition revenue seems to be challenged. Finally, further cost-cutting may be also useful to optimize its SE, it is just that if NKUST attempt to do so, it must be prudential in the potential risk to deteriorate quality of teaching and research, as stressed by [6, 8, 37, 52, 56]. In conclusion, again, the results have fully manifested that the merger could not help the post-merger HEI withstand the shock of declining fertility, but instead have further made the post-merger HEI in larger trouble and challenge, even for a HEI which was efficiency in management and in teaching and research.

TABLE IV. DEA EFFICIENCY SCORES OF NKUST FROM 2012 TO 2020

53 Comprehensive HEIs Efficiency Frontier												
HEI	TE/PTE/SE	2012	2013	2014	2015	2016	2017	2018	2019	2020	Pre-Merger Mean	Post-Merger Mean
NKFUST	TE	0.797	0.777	0.809	0.842	0.812	0.889				0.821	
	PTE	0.844	0.827	0.848	0.849	0.817	0.897				0.847	
	SE	0.944	0.94	0.955	0.991	0.995	0.991				0.969	
		IRS	IRS	IRS	IRS	IRS	IRS					
NKUAS	TE	0.825	0.695	0.724	0.675	0.753	0.822				0.749	
	PTE	0.873	0.755	0.777	0.702	0.764	0.823				0.782	
	SE	0.945	0.921	0.931	0.962	0.985	0.998				0.957	
		IRS	IRS	IRS	IRS	IRS	IRS					
NKMU	TE	0.717	0.705	0.831	0.849	0.848	0.918				0.811	
	PTE	0.840	0.836	0.923	0.892	0.884	0.955				0.888	
	SE	0.853	0.844	0.899	0.952	0.959	0.961				0.911	
		IRS	IRS	IRS	IRS	IRS	IRS					
NKUST	TE							0.845	0.817	0.819		0.827
	PTE							1	1	1		1
	SE							0.845	0.817	0.819		0.827
								DRS	DRS	DRS		

The results of diseconomies of scale and scope in this case accorded with [1–3, 59], while accorded with [7] only in the negative effect of size on efficiency. Also, the result may agree with [8] claim that the resource-intensive HEIs may have to trade off quality and efficiency, and in practice it may be impossible to achieve both. Nevertheless, the result of diseconomy of scale caused by the disparate-scaled merger has diverged with the Chinese evidence shown by [62, 63].

Finally, for the pre-merger HEI, NKUAS, the positive effect on TE following the merger, but only appeared in the first year, the result was consistent with [4–8, 36].

V. CONCLUSIONS AND SUGGESTIONS

This study following up [1], adopted DEA method to verify the efficiency changes and the causes of the changes following the mergers of three cases of post-merger HEIs in Taiwan, specifically, from the long-run perspective, with the data from 2012 to 2020.

Concerning NPTU, after the merger, its PTE was maintained efficiency ($PTE = 1$) and SE boosted in the first four years, though dropped later, deriving its TE the same trend. Until 2020, its TE had not yet recovered to the levels before the merger, no matter in terms of individual year or the mean. Since the states of production were still in the IRS by 2020, it suggested NPTU's proportion increase in revenue was greater than that in cost. The results seemed to manifest that merger of HEIs contributed to optimizing scale, namely, to minimize LAC further, although the effect was not sustained. Besides, since the merger indeed enlarged scale and also expanded diversity in fields and interdisciplinarity, the results manifested the economies of scale and scope following the merger, namely, the LAC decreased with the increased scale and diversity of production. The demonstration of economies of scale and scope was consistent with [21, 33–35, 42, 61], whereas with [7] only uniform in the economy of scope. Finally, since the NPTU constituted two HEIs with equivalent size, the results were discrepant with the findings of [62, 63], both of them revealed research productivity declined after the mergers between HEIs with similar scale in China.

As regards NTHU, the merger made NTHU worse in both of PTE and SE, and the worsened PTE, much severer than its underperformed SE, was the chief cause deteriorated TE. Until 2020, both of his PTE and SE as well as TE had not yet recovered to the levels before the merger, no matter in terms of individual year or the mean. Furthermore, since the NTHU has long been the so-called top university highly funded by 'Aim for the Top University Project' in Taiwan, the degradation of PTE and TE after the merger seemed to agree with the inferences from [21, 30, 34, 35], namely, in the absence of competitive pressure, the higher the public-funding, the worse the use of resources and the lower the efficiency. Further, the deprivation of PTE may be also due to following the merger, the complexity and high costs in management due to much more departments and staff [44], or much more diverged missions to impede administrators and faculty to well time-allocation in their work [45], or the geographic separation of multi-campus [49–51], or due

to the alleviated competitive pressure due to higher market share [37], or due to the still ill-integration in culture identity, academic identity, affective commitment and so on [14, 16, 36, 58, 59]. These still need to be further verified in future research. Also, the result may be consistent with [8] proposition that HEIs were resource-intensive, therefore there was the trade-off between quality and efficiency. Finally, since the NTHU constituted of two HEIs with dissimilar sizes, the results of diseconomies of scale were discrepant with the Chinese evidence of [62, 63]. In short, for NTHU, the deprivation in both of PTE and SE after the merger made clear that the merger could not aid in the better use of resources, nor optimizing scale through economies of scale and scope, and even caused the post-merger HEI's production state into DRS.

In regard to NKUST, after the merger, the PE enhanced to 1.0 and persisted to 2020, i.e., the third year after the merger, however, the sever drop in SE caused the worse TE. Until 2020, his SE and TE did not yet recover to the levels before the merger, regardless in the terms of individual year or the mean. The results clarified that the merger indeed improved the efficiency in management and teaching and research for the three pre-merger HEIs. The results were consistent with [6, 36, 39, 40] in that voluntary mergers promote the better use of resources and thus boost efficiency. Furthermore, since this merger was featured with the diversity in fields and interdisciplinarity and multi-campus, the optimization of PTE (i.e., $PTE = 1$) may be performed by the outstanding staff and students who gathered to the post-merger HEI and promote the better use of resources in management and in teaching and research, that corresponded to the European evidence manifested by [21, 36], the Norwegian evidence shown by [19, 41], the UK evidence shown by [7, 42], and the European and the US evidence revealed by [34, 35]. Nevertheless, the result of the diseconomy of scale caused by the unlike-scaled merger was diverged with the Chinese evidence shown by [62, 63].

To sum up, all of the three post-merger HEIs, NPTU, NTHU and NKUST suffered from regression of SE after the mergers from the lengthy perspective, however, as of 2020, NPTU was still in the production state of IRS, whereas NTHU and NKUST were already in the production state of DRS. The results manifested the diseconomies of scale and scope following the merger, and agreed with [1–3, 59]. Furthermore, the results implied NPTU can further minimize its LAC by expanding its outputs, while NTHU and NKUST cannot. Since all of them have fulfilled the mergers with diversity in fields and in interdisciplinarity and multi-campus, the results suggested all of them should preferably take advantage of multi-field, interdisciplinarity and multi-campus to struggle to develop and innovate more and diverse courses, programs and research that meet the needs of the times, so as to attract more students, more local and national public-funding schemes, more public-private collaboration schemes, more industrial cooperation projects, and even international industrial cooperation projects. By doing so, NPTU could expand tuition revenue and research funding and thus boost its SE due to the economies of scale and

scope, while NTHU and NKUST need to achieve the state that makes the proportion increase in revenue greater than that in cost, and thereby boost its SE mainly due to the economies of scope, as implied by [1, 3, 7]. Apparently, NTHU and NKUST will be much harder than NPTU since they need to raise higher revenue and better control or even largely cut their cost at the same time. Though, in the current context of the severely declining birth rates worldwide, especially in Taiwan, together with the prevailing and persistent government budget cutting, the increase of tuition revenue and public funding seem to be extremely challenging. Besides, further cost-cutting may sacrifice the quality of teaching and research and needs to be prudentially treated, as stressed by [6, 8, 37, 52, 56]. The last but quite importantly, what the most crucial for NTHU right now is to optimize his ability in management and in teaching and research, not only boost his SE. In short, until now, the mergers vividly brought in more dilemmas, especially for NTHU and NKUST.

Moreover, the case of NPTU and NKUAS revealed the results that the no lasting benefit and even deteriorative effect of merger on SE and TE agreed with the evidence from China [4, 5], evidence from England [6–8], and evidence from France [36]. Almost all of them revealed that the positive effect of merger on efficiency was only in the first year, and then reversed to degrade the efficiency.

Furthermore, the case of NPTU and NTHU showed the results were in accordance with [1–3, 59] in their claims. Namely, only efficient HEIs, which had ability to well use of resources and were shown efficient in management and in teaching and research ($PTE = 1$), will boost or maintain post-merger HEIs' efficiency. As shown in the case of NPTU. Conversely, the inefficient HEIs, which engaged poor use of resources and shown as inefficiency in management and in teaching and research ($PTE < 1$), cannot boost or even maintain post-merger HEIs' efficiency. As shown in the case of NTHU.

Finally, from the lengthy perspective to identify the consequence of the merger rather than from short-run ones, as suggested by [7, 8, 11–16, 26, 36, 63], so far all of the three cases brought insight into that their TE all worsen after the mergers. Furthermore, until 2020, their TE all had not yet recovered to the levels before the merger, whatever in terms of individual year or the mean. The results were consistent with [3] in shedding light on the declining fertility rate struck HEIs rapidly and severely in Taiwan, and the mergers cannot be the panacea for higher education crisis. Even, indeed brought to more dilemmas, even for a HEI which was efficiency in management and in teaching and research, as the case of NPTU shown. Moreover, the results that the production states of NTHU and NKUST were all already into DRS after the merger also demonstrated the impropriety of the merger policy for Taiwanese HEIs. The results hence recommended that governments and HEIs should be cautious about the mergers of HEIs in the future, especially in Taiwan, where the birth rate continues to decline substantially. The DRS state of production indicated the two post-merger HEIs have been too large to be efficient scale, and their inefficient scales were deteriorating their TE severely.

Moreover, looking forward to the future, under the worldwide decline of fertility rates, it must be highly challenging for HEIs to upgrade their SE by the raise of tuition revenue. This study thereby suggested that HEIs should take advantage of their multi-field, interdisciplinarity, and multi-campus to develop and innovate new courses, programs, and research that meet the needs of the times, and upgrade their SE by the economy of scope.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

- [1] C. R. Chen, "Effect of merger on efficiencies: A study on Taiwanese higher education," *International Journal of Business, Human and Social Sciences*, vol. 14, no. 6, pp. 480–485, 2020.
- [2] T. Fu, C. Huang, and Y. Yang, "Quality and economies of scale in higher education: A semiparametric smooth coefficient estimation," *Contemporary Economic Policy*, vol. 29, no. 1, pp. 138–149, 2011.
- [3] C. R. Chen, "Efficiency analyses of higher education in Taiwan: Implications to higher education crisis," *International Journal of Business, Human and Social Sciences*, vol. 14, no. 6, pp. 486–495.
- [4] Y. Hu and W. Liang, "The impact of institutional merge in scientific research productivity in higher education: A Malmquist index analysis," *Tsinghua Journal Education*, vol. 28, no. 1, pp. 62–70, 2007.
- [5] Y. Q. Mao, Y. Du, and J. J. Liu, "The effects of university mergers in China since 1990: From the perspective of knowledge production," *International Journal of Educational Management*, vol. 23, no. 1, pp. 19–33, 2009.
- [6] R. I. Capuccinello and S. Bradley, "The effect of college mergers on student dropout behaviour: Evidence from the UK," *Lancaster University Management School Working Paper 007*, 2014.
- [7] M. Papadimitriou and J. Johnes, "Does merging improve efficiency? A study of English universities," *Studies in Higher Education*, vol. 44, no. 8, pp. 1454–1474, 2019.
- [8] J. Johnes and M. G. Tsionas, "Dynamics of inefficiency and merger in English higher education from 1996/97 to 2008/9: A comparison of pre-merging, post-merging and non-merging universities using Bayesian methods," *Manchester School*, vol. 87, no. 3, pp. 297–323, 2019.
- [9] T. Estermann and E. B. Pruvot, "The rise of university mergers in Europe," *International Higher Education*, vol. 82, pp. 12–13, Sep. 2015.
- [10] L. C. Zhang and A. C. Worthington, "Explaining estimated economies of scale and scope in higher education: A meta-regression analysis," *Research in Higher Education*, vol. 59, no. 2, pp. 156–173, Mar. 2018.
- [11] L. C. J. Goedegebuure, *Mergers in Higher Education: A Comparative Perspective*, Utrecht: Lemma, 1992.
- [12] R. M. O. Pritchard and A. Williamson, "Long-Term human outcomes of a 'shotgun' marriage in higher education," *Higher Education Management and Policy*, vol. 20, no. 1, pp. 1–23, 2008.
- [13] J. Tienari, H. M. Aula, and T. Aarrevaara, "Built to be excellent? The Aalto University merger in Finland," *European Journal of Higher Education*, vol. 6, no. 1, pp. 25–40, 2016.
- [14] J. Ursin and H. Aittola, "It's not like everything changes just with a click on New Year's Eve": Perceptions on educational issues of university mergers in Finland," *Higher Education Policy*, vol. 34, no. 3, pp. 543–559, 2021.
- [15] H. Leslie, A. Abu-Rahma, and B. Jaleel, "In retrospect: A case of merger in higher education," *International Journal of Educational Management*, vol. 32, no. 3, pp. 382–395, 2018.
- [16] S. Wollscheid and T. Røsdal, "The impact of mergers in higher education on micro-level processes – A literature review," *Tertiary Education and Management*, vol. 27, no. 3, pp. 257–280, Sep. 2021.
- [17] G. Johnes, "The costs of multi-product organizations and the heuristic evaluation of industrial structure," *Socio-Economic Planning Sciences*, vol. 32, no. 3, pp. 199–209, 1998.

- [18] F. Schiltza and K. D. Witte, "Estimating scale economies and the optimal size of school districts: A flexible form approach," *British Educational Research Journal*, vol. 43, no. 6, pp. 1048–1067, 2017.
- [19] N. Frølich and B. Stensaker, "Mergers and missions: Investigating consequences for system diversity," *Higher Education*, vol. 82, no. 5, pp. 411–434, 2021.
- [20] J. S. Fairweather, and A. L. Beach, "Variations in faculty work at research universities: Implications for state and institutional policy," *The Review of Higher Education*, vol. 26, no. 1, pp. 97–115, 2002.
- [21] J. Wolszczak-Derlacz and A. Parteka, "Efficiency of European public higher education institutions: A two-stage multicountry approach," *Scientometrics*, vol. 89, no. 3, pp. 887–917, 2011.
- [22] J. Johnes, "Efficiency and productivity change in the English higher education sector from 1996/97 to 2004/05," *The Manchester School*, vol. 76, no. 6, pp. 653–674, 2008.
- [23] G. Kempkes and C. Pohl, "The efficiency of German universities: Some evidence from nonparametric and parametric methods," *Applied Economics*, vol. 16, no. 42, pp. 2063–2079, 2010.
- [24] A. R. Buono and J. L. Bowditch, *The Human Side of Mergers and Acquisitions—Managing Collisions Between People, Cultures, and Organizations*, San Francisco: Jossey-Bass, 1989.
- [25] K. Harman, "Merging divergent campus cultures into coherent educational communities: Challenges for higher education leaders," *Higher Education*, vol. 44, no. 1, pp. 91–114, 2002.
- [26] G. Harman and K. Harman, "Institutional mergers in higher education: Lessons from international experience," *Tertiary Education and Management*, vol. 9, no. 1, pp. 29–44, Jan. 2003.
- [27] Q. Zha, "The resurgence and growth of private higher education in China," *Higher Education Perspectives*, vol. 2, no. 1, pp. 54–68, 2006.
- [28] Y. Cai and X. Yang, "Mergers in Chinese higher education: Lessons for studies in a global context," *European Journal of Higher Education*, vol. 6, no. 1, pp. 71–85, 2016.
- [29] Y. Wang, "The quantitative research and analysis on effectiveness of university mergers in China: Mergers of 40 colleges and universities as examples," master's thesis, Antai College of Economic and Management, Shanghai Jiao Tong University, Shanghai, China, 2009.
- [30] P. Aghion, M. Dewatripont, C. Hoxby, A. Mas-Colell, and A. Sapir, "The governance and performance of universities: Evidence from Europe and the US," *Economic Policy*, vol. 25, no. 61, pp. 7–59, 2010.
- [31] G. T. Sav, "Stochastic cost frontier and inefficiency estimates of public and private universities: Does government matter?" *International Advances in Economic Research*, vol. 18, no. 2, pp. 187–198, 2012.
- [32] G. T. Sav, "Effects of financial source dependency on public university operating efficiencies: Data envelopment single-stage and Tobit two-stage evaluations," *Review of Economics and Finance*, vol. 3, no. 1, pp. 63–73, 2013.
- [33] A. Varga and M. Horváth, "Institutional and regional factors behind university patenting in Europe: An exploratory spatial analysis using EUMIDA data," presented at the 35th DRUID Celebration Conference 2013, Barcelona, Spain, 17–19 June 2013.
- [34] J. Wolszczak-Derlacz, "An evaluation and explanation of (in)efficiency in higher education institutions in Europe and the U.S. with the application of two-stage semi-parametric DEA," *Research Policy*, vol. 46, no. 9, pp. 1595–1605, 2017.
- [35] J. Wolszczak-Derlacz, "Assessment of TFP in European and American higher education institutions – Application of Malmquist indices," *Technological and Economic Development of Economy*, vol. 24, no. 2, pp. 467–488, 2018.
- [36] C. Ripoll-Soler and M. de-Miguel-Molina, "Higher education mergers in Europe: A comparative study of the post-merger phase," *Tertiary Education and Management*, vol. 25, no. 3, pp. 255–271, 2019.
- [37] G. D. Fraja and P. Valbonesi, "The design of the university system," *Journal of Public Economics*, vol. 96, no. 3–4, pp. 317–330, Apr. 2012.
- [38] L. Russell, "Better outcomes without increased costs? Effects of Georgia's University system consolidations," *Economics of Education Review*, vol. 68, pp. 122–135, Feb. 2019.
- [39] Y. Cai, R. Pinheiro, L. Geschwind, and T. Aarrevaara, "Towards a novel conceptual framework for understanding mergers in higher education," *European Journal of Higher Education*, vol. 6, no. 1, pp. 7–24, 2016.
- [40] H. D. Boer, J. File, J. Huisman, M. Seeber, M. Vukasovic, and D. F. Westerheijden, *Policy Analysis of Structural Reform in European Higher Education: Processes and Outcomes*, California: Palgrave Macmillan Cham, 2017.
- [41] S. Kyvik and B. Stensaker, "Factors affecting the decision to merge: The case of strategic mergers in Norwegian higher education," *Tertiary Education and Management*, vol. 19, no. 4, pp. 323–337, 2013.
- [42] G. Johnes and J. Johnes, "Costs, efficiency, and economies of scale and scope in the English higher education sector," *Oxford Review of Economic Policy*, vol. 32, no. 4, pp. 596–614, 2016.
- [43] J. Johnes, "Efficiency and mergers in English higher education 1996/97 to 2008/9: Parametric and non-parametric estimation of the multi-input multi-output distance function," *The Manchester School*, vol. 82, no. 4, pp. 465–487, 2014.
- [44] A. Bonaccorsi, C. Daraio, and L. Simar, "Advanced indicators of productivity of universities an application of robust nonparametric methods to Italian data," *Scientometrics*, vol. 66, no. 2, pp. 389–410, Feb. 2006.
- [45] V. L. Hesli and J. M. Lee, "Faculty research productivity: Why do some of our colleagues publish more than others?" *Political Science and Politics*, vol. 44, no. 2, pp. 393–408, 2011.
- [46] A. Bonaccorsi, C. Daraio, and L. Simar, "Efficiency and economies of scale and scope in European universities: A directional distance approach," Technical Report no. 8, pp. 1–29, 2014.
- [47] A. Bonaccorsi and C. Daraio, "Exploring size and agglomeration effects on public research productivity," *Scientometrics*, vol. 63, no. 1, pp. 87–120, 2005.
- [48] T. Agasisti and C. Pohl, "Comparing German and Italian public universities: Convergence or divergence in the higher education landscape?" *Managerial and Decision Economics*, vol. 33, no. 2, pp. 71–85, Jul. 2012.
- [49] A. Puusa and J. Kekäle, "Feelings over facts – A university merger brings organisational identity to the forefront," *Journal of Higher Education Policy and Management*, vol. 37, no. 4, pp. 432–446, 2015.
- [50] N. Frølich, J. Trondal, J. Caspersen, and I. Reymert, "Managing mergers – Governancing institutional integration," *Tertiary Education and Management*, vol. 22, no. 3, pp. 231–248, 2016.
- [51] N. Zeeman and P. Bennenworth, "Globalisation, mergers and 'inadvertent multi-campus universities': Reflections from Wales," *Tertiary Education and Management*, vol. 23, no. 1, pp. 41–52, 2017.
- [52] S. Kelchtermans and F. Verboven, "Program duplication in higher education is not necessarily bad," *Journal of Public Economics*, vol. 94, no. 5–6, pp. 397–409, 2010.
- [53] S. Kyvik, "The merger of non-university colleges in Norway," *Higher Education*, vol. 44, no. 1, pp. 53–72, 2002.
- [54] F. Y. Nyeu, "The implementation of higher education mergers in China," Ph.D. dissertation, Teachers College, Columbia University, New York, US, 2006.
- [55] Y. Cai, *Academic Staff Integration in Post-Merger Chinese Higher Education Institutions*, Tampere: Tampere University Press, 2007.
- [56] M. Safavi and L. Håkanson, "Advancing theory on knowledge governance in universities: A case study of a higher education merger," *Studies in Higher Education*, vol. 43, no. 3, pp. 500–523, 2018.
- [57] L. Evans, "The worst of times? A tale of two higher education institutions in France: Their merger and its impact on staff working lives," *Studies in Higher Education*, vol. 42, no. 9, pp. 1699–1717, 2017.
- [58] T. Fumasoli, R. Pinheiro, and B. Stensaker, "Handling uncertainty of strategic ambitions — The use of organizational identity as a risk-reducing device," *International Journal of Public Administration*, vol. 38, no. 13–14, pp. 1030–1040, 2015.
- [59] C. P. Slade, S. Ribando, C. K. Fortner and K. V. Walker, "Mergers in higher education: It's not easy. Merger of two disparate institutions and the impact on faculty research productivity," *Studies in Higher Education*, vol. 47, no. 6, pp. 1215–1226, 2022.
- [60] G. Curri, "Reality versus perception: Restructuring tertiary education and institutional organizational change – A case study," *Higher Education*, vol. 44, no. 1, pp. 133–151, 2002.

- [61] K. V. Zinkovsky and P. V. Derkachev, "Restructuring the system of higher education assessing the outcomes of university mergers," *Russian Education and Society*, vol. 60, no. 5, pp. 402–421, 2018.
- [62] C. Yuan, H. Sun, and K. Fang, "The effects of institutional change on university knowledge transfer during the transition period: Evidence from the university mergers in China," *Chinese Journal of Management*, vol. 10, no. 3, pp. 451–457, 2013 (in Chinese).
- [63] Q. Liu, D. Patton, and M. Kenney, "Do university mergers create academic synergy? Evidence from China and the Nordic Countries," *Research Policy*, vol. 47, no. 1, pp. 98–107, 2018.
- [64] M. Andrews, W. Duncombe, and J. Yinger, "Revisiting economies of size in American education: Are we any closer to a consensus?" *Economics of Education Review*, vol. 21, no. 3, pp. 245–262, 2002.
- [65] M. J. Farrell, "The measurement of productive efficiency," *Journal of the Royal Statistical Society*, vol. 120, no. 3, pp. 253–290, 1957.
- [66] A. Charnes, W. W. Cooper, and E. Rhodes, "Short communication: Measuring the efficiency of decision making units," *European Journal of Operational Research*, vol. 2, pp. 429–444, 1978.
- [67] R. D. Banker, A. Charnes, and W. W. Cooper, "Some models for estimating technical and scale inefficiencies in data envelopment analysis," *Management Science*, vol. 30, no. 9, pp. 1078–1092, 1984.
- [68] The Laws & Regulations database, Ministry of Justice of Taiwan. National University Endowment Fund Establishment Act, Article 3. [Online]. Available: <https://law.moj.gov.tw/ENG/LawClass/LawAll.aspx?pcode=H0030025>
- [69] National Pingtung University official web. [Online]. Available: <https://eng.nptu.edu.tw/files/15-1150-60349-c5437-1.php?Lang=en>
- [70] National Tsing Hua University official web. [Online]. Available: <http://www.nthu.edu.tw/about/nthuIntr>
- [71] National Kaohsiung University of Science and Technology official web. [Online]. Available: <https://eng.nkust.edu.tw/p/404-1131-36828.php?Lang=en>
- [72] J. P. Chavas, B. L. Barham, J. D. Foltz, and K. Kim, "Analysis and decomposition of scope economies: R&D at US research universities," *Applied Economics*, vol. 44, no. 11, pp. 1387–1404, 2012.

Copyright © 2024 by the authors. This is an open access article distributed under the Creative Commons Attribution License ([CC BY-NC-ND 4.0](https://creativecommons.org/licenses/by-nc-nd/4.0/)), which permits use, distribution and reproduction in any medium, provided that the article is properly cited, the use is non-commercial and no modifications or adaptations are made.