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Abstract

Many activities have been used to impart knowledge and foster the quality of education at higher education institutions, mainly teaching and research. Higher education institutions have typically focused on the adoption of teaching and research independently, but in many instances, both activities coexist. By taking into account the coexistence, this study empirically analyzed why teaching and research activities appear together and how joint adoption of the activities has economic impacts on the performance of the higher education institutions. To do so, this chapter tested the existence of complementarity between teaching and research using supermodularity through the data envelopment analysis approach. Therefore, the empirical result showed that complementarity between teaching and research confirms that the adoption of one activity strengthens the adoption decision about the other activity. This implies that the institutions that execute both activities simultaneously become more productive rather than adopting a single activity. Moreover, it is important for academic decision-makers to take decisions in order to allow universities to achieve economies of scale.

Keywords: complementarity, shared resources, DEA, higher education, teaching and research interdependence

1. Introduction

The term complementary comes from the Latin word “complere” and its meaning is “to fill up.” In many disciplines, particularly in quantum physics, the concept of complementarity is used and most frequently connected with the wave-particle duality [1] and has several implications. In economics, complementary exists when marginal returns from one variable increase the level of another variable [2]. Therefore, the cumulative economic value added when two complementary variables are combined in a production process exceeds the value produced when these production variables are added separately.

In recent years, the notion of complementarity and its function in organizational structure has gained a lot of attention [3]. Complementarity occurs in the broadest sense when two factors improve each other in a way that adopting more of one factor rises the value of adopting more of the other [4]. On the contrary, complementarities
could also lead to undesirable results. For instance, the complementary between factors of closely joined systems may create difficulties in an organization because a change in one factor causes a change in all other factors in the system [5].

The existence of complementarity between variables in an organization might be a powerful performance value. Nevertheless, studies based on the interactions between variables in isolation do not often measure the effects of these performances, as it disregards the contextual variable's role that may be important for the materialization of complementary relationships. It is a phenomenon of system-specific that arises from the embeddedness of individual traits into the relationships among variables in the organizational nexus. On the contrary, this embeddedness cause for both how to control complementarity relationship, and consider for it in scientific studies.

Through the work of Paul Milgrom and John Roberts in economics, the concept of complementarity has become more tractable [6]. They used the mathematical expression of supermodularity on lattices based on Topkis' work [7, 8] as an approach to formally modeling complementarity [2, 9]. This approach modeling the complementarities, which opposed traditional economics concepts in various significant manners: First, two basic production factors are identified by classical economic models and thus, focus on relative factor homogeneity [10]. on the other side, complementarity refers to the concept that comes from the combination of many distinct factors, as Lachmann has already noted [11]. Second, traditional microeconomics claims that design choices are infinitely divisible, that the relationship between them is concave and the constraints are convex. Performance-optimal configurations are identified through local testing based on these assumptions: Decision-makers manage their systems in small steps and analyze the resulting change in performance until they reach a point when the modifications no longer result in additional improvements. In comparison, modeling complementarity as to supermodular function on lattice may operate a condition, where combining of design choice is constituted by local maximum rather than a worldwide event that could occur, for instance, when the payoff function is not continuous. It also shows that design choices are primarily discrete variables rather than continuous variables that can be altered in increments if they can adapt at will. These perceptions have gotten further substantiation by researchers who use the NK-model for the simulation of organizational designs [12–14].

The notion of complementarity plays a significant role in the literature on strategy and organization field. From 1960 to 1970s, the term appeared rarely in the literature [15]. It started to emerge more frequently during the 1980s in the organizational configurations' literature [16–17]. Complementarity is used interchangeably with congruence and fits in this context. The main argument here is that a good fit among contextual factors, organizational design, and strategy can provide an organization a competitive edge over others that do not. Aside from survival, Miller [17] and his coauthors [16] did not make any conclusions about the consequences of organizational fit.

Since Schumpeter's time, numerous research on the complementarity of various innovation types has been done. For instance, studies have concentrated on innovations that include enhancements to products and production processes, as well as enhancements to corporate operations, distribution, and promotion. As a result, the investigations are directed by these innovation patterns to focus on a certain sort of innovation.

Currently, academics are examining the complementarity-in-performance between practices using interaction concept and cluster processes. For instance, Schmidt and Rammer looked into the connection between profit margins and technological
advancement. Both technology and non-technological trends are increasingly being taken into account, and they are interconnected. The outcome demonstrated that nontechnical innovation has significantly less impact on a company’s profit margins than technology innovation. On the other hand, the combination of technical and non-technological innovation has a favorable effect on a firm’s success [18]. Sapprasert and Clausen looked at how organizational and technological innovation affects a firm's performance. The empirical finding demonstrated that both types of innovation together have a favorable and significant impact on organizational performance [19].

The concept of complementarity has been used in a number of areas based on actual evidence. Certified labels and brands, process and product innovation, labor skill and innovation strategies, various government innovation policies, information technology, workplace organization, and new product and service innovation are a few of them. Others include the adoption of various information technologies in emergency health care, the use of various types of labor in the determination of trade patterns, and the use of external knowledge at various stages of new product development.

Generally speaking, the viewpoint of complementarity is not a hypothesis, but the meso-level method that enables scholars to understand the relational phenomena as driving forces that influence both the higher and lower levels of analysis [20, 21]. The concept of supermodularity helps researchers to model the relationships between multiple organizational factors of complex structures in a mathematically rigorous way as “something more than the sum of these factors.” The positive outcomes of such interactions are also referred to as a fit, which in macro-organizational theory has a rich intellectual tradition [22]. Simultaneously, the perceptive of complementarity does not predict the relationships between factors as micro-level theories usually do in organizational behavior.

2. Aspects of higher education institutions

Higher education has long been acknowledged as a useful and significant tool for fostering social and economic development. Following the implementation of plans and initiatives designed to increase higher education’s competitiveness, certain countries have seen the benefits of higher education in terms of the economy, social welfare, and human resources. In addition, higher education is essential for promoting social and economic development.

The problem of students confusing teaching with research is widespread around the world. Reforms must therefore be implemented on both sides, in both educational and research institutions. Few people are aware of the conflicts that arise as students try to understand how research and teaching will play a part in their future careers or how these conflicts affect the formation of their academic identities.

The complex structure of interconnected features of resources, activities, and procedures used by HEIs to construct the institutional framework. For both to be competitive, many HEIs are dedicated to fusing teaching and research. In order to supply a nation with skilled labor, HEIs must deliver top-notch instruction and carry out top-notch research. The institutions must improve their performance because higher education is so crucial to the growth of the nation’s economy. On the other side, institutions have challenges while attempting to increase their effectiveness through the adoption of integrated and coherent procedures.

From the literature on the educational efficiency measure using the DEA approach, two major streams have been identified: First, its objective was to assess
the efficiency of basic education. For instance, the efficiency of secondary schools in Finland, England, and Latin America. Second, its objective was to assess the efficiency of higher education. For instance, higher education in the USA, China, Malaysia, UK, Israel, Australia, Greece, Canada, Taiwan, Poland, and Finland. It is challenging to gauge the effectiveness of HEIs due to certain of their characteristics. Furthermore, pinpointing the precise input levels required to produce the intended outcomes might be challenging. Because of the institution’s complexity and the subjectivity of its educational outcomes, choosing the right performance metrics is quite challenging. However, it is frequently possible to construct a single summary measure of performance in the manufacturing and financial business contexts, such as profit, income, sales, or market share.

Recently, some businesses have started working together to share resources and increase earnings. While using a complementarity theory, other organizations increase their reward by enhancing the effectiveness of their actions. However, a lot of HEIs boost their results by enhancing the effectiveness of each activity separately. As a result, it is crucial to adopt activities simultaneously because doing so increases the connections between them, improves institutional innovation performance, and reduces institutional costs by utilizing specific resources for both activities. Additionally, it helps policymakers, school administrators, and the government track institutional performance and avoid wasting money.

By providing highly skilled labor and novel knowledge, HEIs significantly contribute to the economic development of a nation. The government’s massive budget allocation to the education sector raises the bar for efficient resource usage and accountability. The Higher Education Commission (HEC) does not provide HEIs with a budget, so institutions are forced to start working on alternative strategies in order to increase efficiency and produce financial resources. It is challenging to assess the effectiveness of HEIs due to the drive to generate resources and the complexity of their objectives.

Previous research has demonstrated that higher education can produce higher levels of performance relative to the money invested in it as opposed to the association between educational costs and outcomes. Moreover, the existence of disparate efficiency levels in the education sector has been measured due to low investment in it. Hence, high investment in the educational system correlated with better academic performance.

HEIs are the foundation for high-tech talent growth, the key factors for enhancing the national quality and improving national competitive capacity [23]. Education generally is the cornerstone of every country’s economy. Delivering quality teaching and conducting good research in higher education are important to provide a knowledgeable resource to the country. The center of educational assessment is a value-of-judgment practice to forward recommendations for improvement through a comprehensive collection of educational knowledge and educational values judgment. For instance, some developed countries, such as US and Europe, have an advanced mechanism to explain how to transfer educational inputs to outputs [24].

HEIs have a dynamic structure of interrelated characteristics of resources, activities, and processes to construct the institutional structure. Adopting teaching and research in tandem effectively enables HEIs to provide high-quality teaching and research while also enhancing their performance. Many studies have been conducted on how joint adoption leads to organizational performance improvement [25]. However, the institutions have faced challenges in how to improve their performance via the adoption of the institutes’ activities jointly and coherently [26].
It is frequently possible to construct a single summary measure of performance, such as profit, sales, income, or market share in financial businesses and manufacturing. However, certain aspects of higher education make efficiency difficult to assess, and several metrics of performance are required due to outcomes such as faculty workload and productivity, sponsored research funds, and degrees awarded. In addition, it might be difficult to estimate the exact amount of funds or input needed to achieve the intended results or output levels. As a result of the complexity and diversity of higher education, as well as the subjectivity of educational outcomes, choosing performance indicators is a tough task [27].

Many HEIs in developing nations have recently risen at an exponential rate; nevertheless, the quality of education and the efficiency provided by these institutions has yet to be determined. On the contrary, these institutions are becoming more aware of the importance of boosting quality and efficiency [28]. Governments, private promoters, and policymakers construct institutions of excellence, benchmarking worldwide institutions; society and industry look for institutions that efficiently provide relevant value [29]. Similarly, parents and students seek out educational institutions that are efficient and provide high-quality instruction. It is crucial to figure out how HEIs rank in terms of performance to foster a competitive environment and look for gaps that are lowering performance.

The demand for higher education is growing with time due to the pressure from schools, parents, and other social agencies. This is commonly believed that an awarded degree from a university offers an opportunity for a broader variety of careers and for more interesting and better-paying careers. Another factor in higher education demand is that employers consider a degree as a useful preselection criterion, increase the proportion of the age group that enters the institution, and improve the valuation of education. Such higher education patterns underline the importance of examining quality problems and this, in turn, contributes to a range of methodological issues, for instance, the description of words, international comparability of data, application of various decision-making methods, etc.

Evaluation and analysis of inputs and outputs is a systematic assessment of higher education research, teaching, and other activities, and then the evaluation outcome represents the overall performance of HEI, that is, input efficiency, output efficiency, and the conversion relationship. Teaching and research are conducted well based on the idea of economics [30]. In order to perform an individual’s job on a labor market, the individual must possess a mechanical and theoretical ability needed by a country’s employer and socioeconomic needs. However, most HEIs produce less productive skilled employees and have a gap in fulfilling the economy’s needs and this leads to socioeconomic inefficiency as a whole [31]. In the higher education context, there are methods that have also been used to address efficiency measurement problems.

A better teaching and research performance are a way of providing input for government, manufacturers, business companies and other stakeholders on the performance assessment of HEIs and these activities help to determine the institutions’ production efficiency. It is not because of the large amount of money spent on them but because they have made a huge contribution to the country’s economy and enhanced the reputation of HEIs [32].

Due to the aggravation of budgetary and issue of educational quality, the managerial body of the HEI is able to admit the concept of efficiency and its measurement in making the decision. The presence of various intangible education outcomes is a difficulty when viewing education through the lens of the production model [33]. For example, scholar successes may be quantified by administering standardized tests,
but outputs connected to ethical and aptitude development are difficult to quantify. Even if measure exists, they are inappropriate in order to put decision at the institutional level. However, few managerial bodies ignore external ranking of efficiency to give a good reason for past decisions or develop new educational policies [34–36].

According to earlier research [37–38], more education can provide higher levels of performance compared to the amount invested in it rather than the opposite, where education spending and outcomes are correlated. Research shows that insufficient investment has led to differential efficiency levels in the education system. Therefore, more educational system investment was associated with improved academic performance [39].

Increasing enrollment to HEIs and conducting academic research with limited funding does not imply that the institutions operate at the highest level of efficiency. To evaluate efficiency, the measurement tool for performance is needed to determine the efficiency of the performance of the institution. As the number of enrolled students in the institutions is increasing with time, it is not a matter of choice to operate the institutions efficiently. In order to determine whether the HEIs operate at a high level of efficiency or not, it needs a measurement performance tool to assess the institutions’ efficiency.

HEIs are establishing their own internal mechanize to evaluate to what extent their objectives should be accomplished. According to Ref. [40], self-assessment has a positive impact on strategies implemented to improve the performance and quality of higher education. It is a source of information about the institutions’ performance and then, a benchmark for improving the efficiency and quality of the process. Most of the institutions’ performance is measured and specified their rank at the regular interval and such assessments depend on a collection of specific standards that are called performance indicators [41]. For example, the benchmarks to measure the performance of the university research are the number of supervised PhD theses and the number of publications. Even though the reliability of choosing performance indicators is somewhat complicated, Grade Point Average (GPA) is a widely accepted indicator in HEI. The main indicator for student performance is GPA and the information available from the students’ database system [42].

A nonparametric approach to measuring HEI efficiency has the advantage of allowing for the inclusion of numerous inputs and multiple outputs without the need for any prior knowledge and simply requiring the input and output values. Because of this, the analysis is appropriate even though it is challenging to the observed price of inputs and outputs. Additionally, it provides guidance on how inefficient institutions might become efficient as well as helps distinguish between efficient and inefficient organizations. However, because it necessitates defining the a priori functional form of the production frontier, the stochastic frontier analysis evaluates the efficiency of the institutions with a specification bias.

3. Relationship between teaching and research

The teaching profession is an outcome of research and a scholar’s activity is vital to organize the strategies of higher education. Thus, teaching and research are interlinked activities. According to Refs. [43, 44], a good higher education scholar should be active in research activity. Hence, there is no separate teaching effectiveness measure since research proficiency can be used as a proxy for teaching effectiveness.
Students’ equating of teaching and research is a well-known issue all around the world. Reforms in both education and research institutions are therefore necessary for the areas of teaching and research. Few people are aware of the conflicts that arise as students attempt to understand how research and teaching will play a part in their future professional lives, let alone how these conflicts will affect their growing academic identities.

Obviously, students benefit from effective links between teaching and faculty research; faculty members benefit from the satisfaction and efficiency of integrating their main professional obligation; higher education benefits when stakeholders are conscious in which they consider their educational mission because a positive public image can translate into governmental financial support. According to Ref. [45], there are numerous reasons to strengthen the teaching–research connection at both institutional levels and individual faculty members. Some of the reasons include trying to bring research into the classroom, student involvement in research projects, and continuing to expand academic scholarship models.

There are conditions to facilitate for integration of research and teaching in higher education. These are: instead of being told what to teach, academics should be active in the decision-making process; research is a broad term that encompasses both creative works and teaching scholarship and integration is also influenced by student awareness [46, 47]. According to Refs. [48, 49], students in the English department perceive research as something they did and as a way to collaborate with academics; students in the geography department see research as mainly noticeable in the field conducted by lecturers and students, and students in the physics department see research as visible when laboratories and machines are open. Hence, the integration of research and teaching is influenced by factors such as well-designed curricula at all levels, government support for teaching and research, and the role and goals of research funding bodies.

From the work of Zubrick [50] and Brown [51], the relationship between teaching and research is a debated issue. Many beliefs have been reported as a result of the debate. From this point of view, Hughes [52] concluded that “Our understanding complex and dynamic relationships between teaching and research is only going to be furthered from a perspective of healthy skepticism rather than mischievous vested interest.”

Many studies have been conducted to clarify the relationship between teaching and research, and this concept has evolved in higher education in recent years. For instance, about 33 institutions were encouraged to implement teaching and research together on some level as a result of the survey of institutional strategies and teaching and learning plans of the 39 publicly funded universities in Australia. On the other, the Australian Quality Agency revealed that many universities intended to adopt these activities concurrently but did not adequately translate them into practice because the institutes did not understand the significance of combination well before adoption [50]; educational administrators believe that the faculty needs to engage separately to achieve the goal of teaching and research and are distinct activities [53]; faculty of research and teaching roles are fragmented, and time spending by faculty members to achieve the goals of the research is not necessarily time to achieving for goals of teaching. On the opposite, policy analysts believe that the roles of faculty members in achieving goals of teaching and research do not always involve distinct and separate use of time. In other words, staff members occasionally mutually produce research and teaching. Hence, the roles of research and teaching are occasionally integrated, and faculty member is sometimes involved in activities that carry out research and teaching goals at the same time [54, 55].
The advantages of combining teaching and research in higher education have been outlined by researchers to professionals, administrators, and academic staff in order to shape higher education decision-making policy and spread ideas about higher education policy setting. Some of the works on this topic deal with how academic excellence is measured and attained as a result of collaborative adoption, knowledge transfer, institutional resource allocation, economic size in universities, and competitive pressure.

4. The complementary of teaching and research activities

4.1 Relative efficiency of HEIs

The efficiency measurement of HEIs was carried out through the output orientation DEA model. The teaching, research, and overall efficiency of 40 HEIs under observation are given in Table 1.

As we observed from the result of the efficiency scores of HEIs in Table 1, the mean and minimum score of the overall (join) efficiency of HEIs is greater than the mean and minimum score of teaching efficiency of HEIs. And also, the mean and minimum score of the overall (join) efficiency of HEIs is greater than the mean and

<table>
<thead>
<tr>
<th>DMU</th>
<th>Efficiency scores for teaching</th>
<th>Efficiency scores for research</th>
<th>Overall efficiency</th>
<th>Ranking of DMU based on its overall efficiency</th>
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<tr>
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minimum score of the research efficiency of HEIs. Moreover, there are some HEIs that are efficient in either teaching or research is also efficient in their overall efficiency. This implies that each activity has a positive impact on the overall efficiency, and institutions that execute both activities simultaneously have better efficiency scores rather than adopting any one activity. Therefore, the institutions adopting both activities simultaneously are more beneficial rather than adopting a single activity. This indicates that the joint adoption of both activities follows economies of scale.

The number of faculty members is a proxy for the size of the HEI. Overall efficiency results indicate that smaller HEIs or universities with a smaller number of faculty members were performing better in transforming input resources into higher outcomes. Bigger HEIs might be restructured to new demands with lesser difficulty as they have established flexible structures. Our findings are in line with the theory of economies of scale. That is, HEIs seem to benefit from the reduction of cost per unit of output by adopting the other activity when one is in practice. This also strengthens the theory of complementarity, where one activity gives more power to output when the other activity is already in practice. Our results are in line with the finding concluded by Long [56] that economies of scope exist for the adoption of teaching and research in combination. However, these results should be generalized with caution of heterogeneity. HEIs would further increase efficiency by giving the same emphasis on teaching and research because the implementation of these activities simultaneously allows them to build their own core skills and gain more benefits. Therefore, institutes that have jointly adopted both activities are substantially more likely to achieve higher performance in those activities.
5. Summary

This chapter showed the following empirical results: Firstly, the joint adoption of teaching and research leads to better HEIs’ performance rather than the adoption of a single activity. This result strongly supports the argument that there is joint interdependence between teaching and research and enhances the existence of complementary. Secondly, in HEIs, teaching is more uniform than research. The difficulty in getting research funding and funding research activities with limited financial resources is likely the cause of the variation in research productivity. Additionally, by contrasting public and private institutions, it was possible to gain insightful information about how the grouped HEIs that are private institutions prioritize teaching over public action. However, compared to private institutions, public institutions place a greater focus on research productivity. The efficiency ratings of the HEIs could also help other stakeholders and decision-makers in the educational sector choose more effective methods to allocate resources. Additionally, the educational management of HEIs allows for the classification of the institutions that have superior comparative efficiency or not and uses the group of HEIs as role models. Abbott [57] and Avkiran [58] contend that efficiency analysis leaves out factors that contribute to inefficient resource distribution among institutions while evaluating educational institutions. The joint implementation of these initiatives in higher education increases the ability to introduce process innovations, such as new methods of instruction, and the faculty members update their knowledge with the most recent information. Furthermore, improving the HEIs’ performance demanded a top management concern. For that reason, higher educations are experimenting with its process, combining teaching and research activities. Therefore, educational administrators or policy-makers require tight integration of teaching and research with the HEIs activities to capture the positive effects and each activity has a marginal return of the other.

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