PUBLIC FUNDING SYSTEM FOR THAILAND HIGHER EDUCATION

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ABSTRACT

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This study employs a two-stage double-bootstrap Data Envelopment Analysis (DEA) to evaluate efficiency of Thai public Higher Education Institutions (HEIs) and investigate the relationship between public funding and HEIs' efficiency. The results from the first-stage analysis disclose a rather high level of average teaching efficiency score, but low level of average research efficiency score. From the analysis of scale efficiency, the findings reveal that teaching inefficiency of Thai public HEIs is mainly caused by inappropriate production scale. Contrarily, research inefficiency of Thai public HEIs is mainly caused by the ability to manage their resources for producing research but not the scale of production.

The results from the second-stage analysis indicate that there are two important factors having positively contribution to teaching and research efficiency: the ratio of public funding to Full Time Equivalent Students (FTEs) and the degree of HEIs' management autonomy and flexibility. Only budgetary factor negatively influencing on teaching and research efficiency is the percentage of HEIs' investment expenditure. Besides, the government's share in HEIs' revenue has negative effects on teaching efficiency, but positive effects on research efficiency.

This study, therefore, suggests to Thai government that (a) public funding to HEIs based on numbers of FTEs should be increased and mechanism to allocate public funding should be related to HEIs' performance; (b) to improve teaching and research efficiency, HEIs should be encouraged to increase mobilization of resources by providing an environment and incentive which makes clear about the benefits of educational support; (c) the revolution of the public HEIs to an autonomous status

should be strongly encouraged by: separating out the two roles of national government agencies in the HE Sector; aligning academic and non-academic autonomy; strengthening accountability mechanisms; creating the enabling environment for HE Reform. Finally, to improve HEIs efficiency the following specific changes should be implemented for inefficient HEIs to approach the best practices: improving teaching quality; improving faculty incentive and evaluation systems; constructing better align curricula and instruction with labour market needs; developing HEIs-based research efforts being consistent with individual institutional missions; and improving public-private and cross-border research partnerships.

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ABBREVIATIONS

Abbreviations	Equivalence
ADB	Asian Development Bank
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DRS	Decreasing Return to Scale
FTEs	Full Time Equivalent Students
HE	Higher Education
HEIs	Higher Education Institutions
IRS	Increasing Return to Scale
OEC	Office of Educational Council
OECD	Organization for Economic Cooperation and Development
OHEC	Office of Higher Education Commission
ONESQA	Office for National Standards and Quality Assurance
RTS	Return to Scale
SAR	Self-Assessment Report
QA	Quality Assurance
VRS	Variable Return to Scale

CHAPTER 1

INTRODUCTION

1.1 Significance of the Problem

The role of Higher Education (HE) in promoting labor productivity, competitiveness and economic growth is being recognized than ever before. In fact, HE has been neglected from the development agenda, largely because investment in HE is costly (Glewwe & Kremer, 2006) but yield lower social returns compared to investment in primary and secondary education (Psacharopoulos & Patrinos, 2004) frequently making HE be viewed as expensive and inefficient public services. Moreover, the belief that primary and secondary education is more important than HE for economic growth and poverty reduction, particularly in developing countries has also contributed significantly to such neglect (Tilak, 2003; Bloom, Canning, & Chan, 2006). These evidences are extensively used to discourage public funding and attention in HE while concentrating rather exclusively on primary and secondary education.

Recently, those arguments are increasingly challenged. To survive in knowledge-based economy with complex and intense competition, only primary and secondary education graduates are not sufficient to manage the modern economies (Asian Development Bank: ADB, 2011). Countries increasingly require workers with skills and knowledge beyond primary and secondary education. Therefore, the role of HE has substantially recovered as a vital engine of economic development in the knowledge-based economy where skilled labor and technological capability are the key factors of productivity, competitiveness and economic growth.

Although, the discussion on whether HE is more significant predictor of sustainable growth and development than basic education particularly in developing countries continues to be debated, there is a consensus that HE has a positive effect on a level of growth and development, regardless of the country's development level, such as Wolff and Gittleman (1993), Sianesi and Reenen (2003), McMahon (1998), Tilak (2003), Bloom, Canning, and Chan (2006), and Gyimah-Brempong, Paddison, & Mitiku (2006).

According to Tremblay, Basri, Arnal, and Santiago (2008), the contribution of HE to sustainable growth and development is presumed to occur through a number of distinct yet interacting functions of Higher Education Institutions (HEIs): 1) the formation of human capital-primarily through teaching; 2) the production of knowledge base-primarily through teaching research and knowledge development; 3) the diffusion of knowledge-primarily through interaction with knowledge users; and 4) the transmission of knowledge primarily through inter-generation storage and transmission of knowledge.

In case of a country which stuck in "a middle income trap" for a long time like Thailand, HE is very necessary because it plays an important role in maintaining economic growth and climbing the income ladder by providing the high-level skills and research to apply current technologies and to assimilate, adapt, and develop new technologies which are the two drivers of productivity enhancement (Di Gropello, 2011).

However, the role of Thai HE is questioned due to the evidence of its performance. According to the latest 2016-2017 Global Competitiveness Report of World Economic Forum, Thailand's score on the area of "higher education and training" is low. Its rank is 62 out of 138 countries. Compared to other key Asian trading partners, Thailand is lagging behind Singapore (2), Malaysia (39), Hong Kong (22), Taiwan (9), South Korea (17), and Japan (21).

Thai HE system has encountered several problems in term of input, process and output/outcome of educational production. Office of Education Council: OEC (2003) reported in "Strategies and Roadmap For Higher Education Reform in Thailand" that the noticeable problems of Thai HE system are: the lack of unity in policies, goals and directions; the absence of a strong and effective mechanism to monitor and evaluate the performance of HEIs; the lack of mechanism to support and assist HEIs in initiating and developing innovations; the lack of flexibility and efficiency in the administration and management of HEIs; and the absence of cooperation within and outside the institutions. Besides, HE also confronts with four more important problems: the equity in accessing to HEIs (Kirtikara, 2001;

Sangnapaboworn, 2003); HE public funding system (Puntasen et al, 2003; Weesakul, B., Charsombat, P., Ratchapaetayakom, J., & Chinnamethipitak, K., 2004; Tangkitvanich & Manasboonphempool, 2011); learners and educational personnel quality (OEC, 2009); and the structural mismatch between offered and needed skills (Di Gropello, 2011). Among various issues confronting the Thai HE system, its public funding system should be primarily concerned as it is more than merely a mechanism to allocate financial resources to HEIs and students but a crucial way to improve the unsatisfactory performance of the HE system.

The government can utilize public funding as a set of tools and other governance instruments to enforce a HE common goal set (e.g. access, efficiency), organize incentives for certain behavior (e.g. competitive research grants), and maximize the desired output with limited resources (Jongbloed, 2010). Additionally, changes in funding system, that is, shift in source of financial resources and/or in the form of resources allocation will likely have a major impact on the behavior of HEIs as well as their internal process of resource allocations (Liefner, 2003). Moreover, the type of adopted funding mechanism will have different effects in various aspects of the HEIs' operations, such as equity of student access, autonomy of institutes, influences from funding sources, competition among institutes, stability of institutes, responsiveness to students and labor market demands, quality of education, and the fiscal burden of the government as well as tax payers and household (Cheung, 2003). However, under different allocation systems, government and HEIs must be accountable for their actions and their spending, meaning that resource allocation and accountability are intertwined. Without accountability, HEIs may engage in too many researches and scholarships, yet, fail to respond to student needs and become inefficient (Nkrumah□Young & Powell, 2008).

Many empirical studies indicate the correlation of public funding system with HEIs' performance such as McPherson and Schapiro (1990); Liefner (2003); Amaral, Rosa, and Tavares (2007); Strehl, Reisinger, and Kalatschan (2007); Frølich, Kalpazidou, and Rosa (2010). The common objective of these studies is to understand how different public funding systems affect institutional strategies and behavior of academic executives which eventually result in HEIs' performance, and cause unintended effects to HE outcomes. The research significant results reveal that the public funding systems have major influences on HEIs' performance through HEIs' strategies in responding to the public funding mechanisms.

In Thailand, the public funding system for HE is suffering from a number of problems, even though, the significant amount of public money has been allocated to the HE sector. The following six problems are the examples.

1) Supply-side financing system. Most of the public expenditures are directly channeled to HEIs. Approximately 80 percent of the public expenditure goes to HEIs, while the remaining is used for student loans (Tangkitvanich & Manasboonphempool, 2011). Under this system, HEIs recruit students for the student loans that do not give students free will to choose HEIs for their study. As a result, the student loan mechanism does not create an incentive for HEIs to create a wider variety and flexibility in the provision of education satisfying the needs and preferences of their students. HEIs which are incapable of providing the kind of education that people want won't relatively attract more students and hence have more money to secure their existence (Jongbloed & Koelman, 2000). Moreover, the allocation mechanism of supply-side funding is unable to induce potential students to study in fields such as science and technology.

2) Improper government budgets for public HEIs. The larger part of government budget for public HEIs is spent on maintaining an operation of the institution and increasing the number of recruits. About 30 percent of the government higher education budget is spent each year on the constructions of new buildings and acquisitions of new equipment. There is usually a smaller amount of budget left for quality development projects (Weesakul, B. et al., 2004).

3) High subsidized by the government.Enrollment in public HEIs is highly subsidized by the government resulting in tuition fees that are set too low and do not reflect the actual cost of production. A study by King Mongkut's University of Technology Thonburi (King Mongkut's University of Technology Thonburi: KMITT, 2005) shows that, on average, a social science student is subsidized by 57 percent of the operating cost while a public-health student is subsidized by 77 percent. Moreover, as the poor are generally under-represented in the HE system, its over subsidization is possible to be regressive. Base on a benefit incidence analysis, the subsidy per capita actually grows with household income (Tangkitvanich & Manasboonphempool, 2011).

4) Insufficiency of government budget on education expenditures. The rapid growth of participation in HE has exerted a lot of pressure on the current education funding system. In particular, the growth of budget on education expenditures has not kept pace with the growth in the number of students enrolled. As a result, public expenditure on education per student has experienced a long-term downward trend. Since education investment has an impact on its quality, there is a risk of quality deterioration unless there are other financial resources that grow sufficiently quick (Tangkitvanich & Manasboonphempool, 2011).

5) Inefficient public funding allocation mechanisms and HEIs' budgeting system. Although the performance-based budgeting has been put into practice since 2004, public funding for HEIs has not yet based on its performance. It is supply side-driven, i.e. changes are mainly due to new study program or research units. Basic funding for HE is still allocated via line-itemized budget according to activity plans and budget proposals that are adjusted incrementally on a year-to-year basis. Moreover, it is related to bargaining power of HEIs (Liefner & Schiller, 2008). Furthermore, HEIs employ fiscal accounting but separate public budgets from their own income which further split among faculties making it almost impossible for administrators to assess the financial status of the HE institutions or to monitor their expenditures (Weesakul, B. et al., 2004). As a result, the present funding mechanism for HE in Thailand is still inadequate and not aim to enhance the goals of its HE system.

6) Overlapping and incoherence between the government units relating to HE funding system in Thailand. Unconformity exists between government units responsible for determining policies and quality control (Office of Higher Education Commission: OHEC) and the budget allocation and performance evaluation unit (Bureau of the Budget: BOB). BOB directly allocates budget to HEIs according to necessities and acceptable budgeting, including HEIs' development plan of non- cooperation with OHEC which has authority to determine policy and development plan for the HE system. The non-corporation between OHEC and BOB causes the imbalance between demand and supply of education leading to the waste of educational resources. It also affects OHEC effectiveness in monitoring and controlling the quality of education, especially by using public funding as a key tool.

The assessment results have not been utilized as an instrument for supervising HEIs to improve their quality and attain the standard required by OHEC.

As abovementioned, the good performance of HE is the basic requirement for Thailand to overcome the middle income trap and climb up to higher income ladders. Furthermore, HE performance can be improved by using the public funding system as a governance instrument for monitoring, following up and supervising HEIs to function with quality; attain the standard required through efficient administration and management; and be in consonance with the policy and direction for national development.

Hence, in order to improve HEIs' performance, the HE public funding system might be employ as a governance instrument; however the public funding system for Thai HE is facing a number of problems as revealed above.

Therefore, it is fascinating to investigate whether the current public funding system for Thai HE can be employed as the governance instrument to improve the performance of HEIs. Simultaneously, it is also important to further explore whether the performance of Thai HEIs could be affected by factors other than the HE public funding system.

The study focusing on the influences of HE public funding system on HEIs' performance is necessary because it is expected that an understanding on the impacts of the system with regard to revisions of related theories and empirical evidence might provide a framework to further develop the public funding system as a governance instrument to improve HEIs' performance. It is also hoped that the study will provide a broad framework which future research can use in studying how change in public funding system for HIEs or other related policies affects its performance. Moreover, the empirical study about the effect of HE public funding system on HEIs' performance is non-available in Thailand, as the author knowledge. Most literatures found in the context of Thai HE system such as Kantabutra and Tang (2010), Wongchai, Liu and Peng (2012), and Sriboonchitta, S. (2012) focus only on the measurement of HEIs' performance without involving with a public funding system.

For these reasons and necessities, this study will attempt to, first, evaluate the performance of Thai public HEIs, and second, investigate the relationship between public funding system for HEIs and their performance in order to address whether the performance of Thai public HEIs could be improved by using the public funding as a tool.

1.2 Research Questions

The main focal point of this study is developing public funding system for HE in order to function as a governance instrument in monitoring, following up and supervising HEIs to perform with quality; to attain the standard required through efficient administration and management; and be in consonance with the policy and direction for national development. Therefore, the research questions of this study are:

1) Can the public funding for Thai HE be employed as the governance instrument to improve the performance of HEIs?

2) What are alternative factors affecting the performance of HEIs other than public funding for HE?

1.3 Objectives of the Study

In order to address the above questions, the objectives of the study are as follows:

1) To measure the performance of Thai public HEIs;

2) To investigate the impacts of public funding for HE on Thai public HEIs performance;

3) To determine and analyze factors affecting the performance of Thai public HEIs.

1.4 Scope of the Study

To investigate the effects of public funding for HE on HEIs' performance in Thailand, yearly data during 2010-2012 from 79 public HEIs (14 autonomous universities; 16 traditional universities; 40 Rajabhat universities; 9 Rajamangala Technical universities) have been employed.

In general, there are two types of HE public funding allocation mechanisms that are used in countries around the world: 1) supply-side financing which make resource transfers directly to institutions for the support of recurrent expenses, capital investments, specific purposes, and research, and 2) demand-side financing that indirectly support institutions through resources transfers, vouchers and subsidies provided to students or their families in the form of grants and scholarships, tax benefits, and subsidized loans to defray or delay the cost of tuition fees or related non-educational expenses such as housing, food, and other living expenses (Salmi & Hauptman, 2006). For this study, supply-side financing is focused, because public funding for Thai HE is mainly allocated to HEIs by the supply-side financing mechanisms. In addition supply-side financing is more directly related to the performance of HEIs than demand-side financing.

In order to evaluate HEIs' performance and effect of public funding on HEIs' performance basing on two main missions of teaching and research, the performance of HEIs is scrutinized into two dimensions, teaching efficiency and research efficiency.

1.5 Benefits of the Study

The results of an attempt to evaluate performance of Thai HE system and determine factors affecting HEIs' performance may provide a richer body of knowledge on policy implementation models to improve Thai HEIs' performance. Moreover, the government funds allocation mechanism designed in this study may provide policy makers a principle to allocate public resources for HEIs, in such a way that improves HEIs' performance.

CHAPTER 2

THAI HIGHER EDUCATION SYSTEM

This chapter provides general background of Thai Higher Education (HE) system in order to use this information as a framework for better understanding of its present characteristics of Thai HE system. The focus of this chapter is organized as follows: section 2.1 an overview of the historical development of Thai HE sector, according to major changes of Thai education system and in order to expand an insight of the HE system in Thailand, current states of HE, in term of governance, structure, and implemented quality assurance system are examined in section 2.2, 2.3, and 2.4, respectively. Moreover, an explanation of public funding system for Thai HE as a key factor affecting HEIs' performance is presented in section 2.5

2.1 Historical Development of Thai Higher Education System

The objective of this section is to explore historical evolution of Thai HE in term of its background, key occurred changes, and factors influencing the changes in order to clearly understand its present Thai HE system. With modifying from Fry (2002), Fry and Bi (2013), and Sae-Lao (2013), the historical development of Thai HE, in this study, is categorized into 4 periods: 2.1.1) the period of modernization, 2.1.2) the period of rapidly educational expansion, 2.1.3) the period of globalization, and 2.1.4) the period of Asian economic crisis and its aftermath. These four historical phases portray the development of Thai HE in parallel with social, economic, and political changes from the late 19th century until the late 20th century.

2.1.1 The Period of Modernization (1889-1959)

Thai HE system had a long history of development. Its beginning can be dated back to the last 19th century in the reign of King Rama V (1868-1910). At that time, the critical pressure facing Thailand was Western colonialism expansion. The western colonialism expansion had driven King Chulalongkorn (King of Rama V) to inescapably reform the country from a traditional into modernization society by embracing western knowledge aimed to alleviate the threat of western power under the condition of preserving country's independence. Essential to the reforms was the creation of modern education in all levels, with the capability to serve the whole kingdom (Fry, 2002).

Among many of the early developments in Thai education, the establishment of HEIs was viewed as the major reform of Thai education. Because the main purpose of establishing HEIs in the period of modernization was to create the modern bureaucratic system as a vital instrument for modern centralized state by preparing an adequate number of literate civil servants. In other words, HE was employed as one of the political tools to circumvent the Western colonialism, from the colonialism's justification that Thailand was uncivilized and barbarian state (Rungfamai, K., 2008). However, owing to the scarcity of resource and opportunities, modern education was limited to the royal family, nobility and commercial elite (Wyatt, 2003).

The formation of the Medical school by royal decree at Siriraj Hospital in 1889 was the first modern HEIs in Thailand. Eight years later in 1897, the Law school under the responsibility of the Ministry of Justice was created. After that, the Royal Pages' school (which was upgraded to a civil servants college in 1910) for providing general education and training in government administration was founded in 1902. Ten years later, the Engineer School was created at Hor Wang in 1913.

Actually, the important change in Thai HE system was an establishment of the first university in 1917, Chulalongkorn University (CU), as a fully-fledges university. CU was founded by drawing together the previously created institutions-the Medical school, the Law school, the Royal Pages' school, with two newly created schools-the school of arts & sciences and the school of political sciences. Inevitably, the chief purpose of CU's foundation at that time was to provide proper training and prepare civil servants to serve in various departments of the government. The establishment of CU was greatly influenced by French concept of la grande école or the great school founded on the base of elitism and intended to train high ranking civil servants to serve nation-building (Watson, 1981).

The development of Thai HE in the later period occurred after the political regime shift from absolute monarchy to constitutional monarchy in 1932. This event led to government's increasing demand for educated political leaders and civil servant knowledge, based on the principle of democracy. In order to train a new type of bureaucracy that would favor service to the state rather than to the monarchy, the second university, Thammasat University (TU), was created in 1933 by the leader of the coup, Pridi Panomyong (Baker & Phongpaichit, 2014). At first, TU was founded as Open University, imitated the University of London, which allowed all people who had complete secondary education level or equivalent academic qualification to acquire HE (Watson, 1989). Moreover, in contrast to CU, TU was free from state's control but had a close relationship to the Ministry of Justice and the department of Public administration. The governance system of TU was under the control of university council, followed the French HE model. However, TU was eventually placed under the state's control in 1952.

After the foundation of TU, four specialized universities were created in Bangkok metropolitan area in an attempt to respond to the in country's manpower demands, and to create greater opportunities of accessing to HE system. In 1942, the University of Medical Science-Mahidol University (MU)-was founded under the responsibility of the Ministry of Public Health. A year later, in 1943, the Fine Arts University-Silapakorn University (SU)-was created under the jurisdiction of the Ministry of Education. At the same time, the Agricultural University -Kasetsart University (KU)-was also created under the supervision of the Ministry of Agriculture. The last specialized university opened in 1954 was Prasan Mitr College of Education under the control of Ministry of Education. At that time, it was opened as a teacher-preparation college and later upgraded to university status and renamed Srinakarinwirot University (SWU).

In sum, the outstanding features of Thai HE in the period of modernization were as follows. Firstly, although Thailand was never colonized, Thai HE had been extensively formed after European models with some degrees of independence to develop HE system without direct foreign domination (Altbach, 1989). Nonetheless, the interpretation of European models in the difference contexts altered its original idea. In Thailand, these models were generally interpreted as by the ruling elite with a view to maintain their authority through putting the institutions under strictly state control (Varunee Osatharom, 1990). As a result of mainly run by the ruling elite to specifically train civil servants, the development of intellectual base inside the universities remained marginalized. Moreover, under the complete state control, it generated strong bureaucratic norms inside Thai universities which later affected the way they conducted their administration and responded to changes (Nilphan, 2005). Secondly, because the expansion of HE system during the period of modernization resulted from the attempt by several government agencies to meet their manpower demands, most universities were established to provide training for civil servants in a different disciplinary accordance to government agencies' requirement, and usually interpreted as professional school for government rather than as communities of scholar engaged in research and the purist of truth (Ketudat, 1972). Moreover, as these universities were under the auspices of different government agencies, they had a close relationship with those agencies who supervised them. As a result, HE quality during this period was driven by bureaucratic rationale rather than by academic excellence (Sae-Lao, 2013). Thirdly, all the six created universities in the period of modernization were located in the capital, Bangkok, because they were specialist institution, and closely associated with specific government agencies. Consequently, there existed the disparity in educational opportunities between urban and rural areas.

2.1.2 The Period of Rapid Educational Expansion (1960-1989)

A steady and remarkable expansion of HE system in Thailand could be witnessed after the end of Second World War (1939-1945). The significant change began in late 1950s and early 1960s when the country launched its first National Economic and Social Development Plan. Moreover, at that time, due to the proliferation of the United States' power after the World War II and increasing attention to prevent the spread of communism and the growing conflict in Vietnam, the United States started to expand its influence into Thailand in term of military assistance, economic and education aids.

During this period, Thailand confronted with many pressures resulting in significant changes in HE system. The first pressure was the growing demands of the country for more highly skilled labour on the establishment of a series of National

Economic and Social Development plan, since 1961, to increase the pace of social and economic development. Certainly, in order to satisfy these developments, HE system would be expected to play an essential role in training manpower in certain areas including engineering, agriculture, medicine, and science. Moreover, as a result of the Thai economic boom in late 1980s, considerable foreign investments were attracted to the country. This, also, unsurprisingly created a notable demand for skilled labour. The second pressure came from the rapid population growth during 1960s. This phenomenon unavoidably caused difficulties to Thai HE system from the increasing number of students that moved from primary to second levels and required more places in HE system. The third pressure, which mainly based on security consideration, was the communist threats in neighboring countries of Indochina and Burma and in the rural regions of Thailand. The Thai government tried to expand all aspects including education (Chaloemtiarana, T., 1979) especially in the rural areas which had suffered from years of benign neglect on the part of central government, and which had not benefited from the economic development of Bangkok and the central plain (Watson, 1989). The *last* pressure for changes in The HE system took place from the escalating political stress from upward strength of opposition forces to strict state-control system which caused the student uprisings in October 1973. The power of student movement to resist authoritarian military government reflected the active role of HE system in the country's political process that had never been occurred. It was the first time that universities were able to challenge the state authority. The pressures, as mentioned above, originated remarkable changes in Thai HE system in term of administrative changes, emergence of new university, and innovative changes (Watson, 1981).

With regard to administrative changes, there existed four important changes in Thai HE system as a result of policy responsiveness to the pressures. Firstly, it was the establishment of the National Education Council (NEC) as a part of the Prime Minister's Office, in 1959. The NEC had special responsibility for coordinating all policy decisions regarding HE and was commissioned with planning the future shape of its system. Instead of being under the authority of various government agencies, the control of all existing universities were transferred to this body. Secondly, in 1963, the Central Clearing House, modeled after the Universities and Colleges Clearing

Association (UCCA) in the UK, was created to guide students to course and institutions most suited to their need and aptitudes as well as the country requirement. Thirdly, in 1967, the University Development Council was founded to develop postgraduate courses related to labour requirements and economic needs. Lastly, the State Universities Bureau, later renamed the Ministry of University Affairs (MUA) was established, in 1972. Much of work of the NEC relating to HE system was transferred to this ministry. The MUA is responsible for broad policies relating to HE system, and acting as a link between the universities and government.

Regarding emergence of new university, there were three new universities established in three different provinces and in three regions of Thailand: Chiang Mai University (CMU) in the north in 1964, Khon Kaen University (KKU) in the northeast in 1965, and Prince of Songkla University (PSU) in the south in 1968. These regional universities were created based upon American and Canadian Models for the new structure of access, credit, form of assessment and administration (Watson, 1989). Significantly, however, the entrance requirements were not radical changed. Moreover, unlike the specific universities in the earlier period, they were multi-faculty institutions which did not specially link with any of government departments and therefore there were not necessarily a training ground for civil servants. They were also designed to generate agricultural and economic development; to simulate local employment opportunities; to meet increasing demand for HE among rural youth thus prevent the drift of brighter students to Bangkok; to improve the standard of general education in the provinces; to engage in economic, social and cultural activities and conduct research as in each region.

In addition, there were other important developments in HE system occurring in the late 1960s and early 1970. There was the establishment of National Institute of Development Administration (NIDA), Asian Institute of Technology (AIT), King Mongkut Institute of Technology (KMIT) and Srinakarinvirot University (SWU) in 1966, 1967, 1971 and 1974, respectively. NIDA was founded as a graduate institution specializing in public administration, applied statistics, business administration, development economics and research training for government officials. In the field of technology, AIT and KMIT were primarily responsible. AIT was created as an autonomous international graduate school which provided sciences and engineering to students from all Asia and beyond. While, KMII was the country's first technological university, formed through amalgamation of a number of existing small technical schools in and around Bangkok. Three years later, a similar amalgamation came about when seven colleges of education were combined and promoted to university status as SWU.

Despite, HE diversification and expansion in 1960s, the limited place in HE remained the apparent problem. Watson (1981) stated that only 25% of candidates in 1963 secured entry to HE. By 1971, the percentage increase to 30% but the position was still inadequate. Accordingly, the Private College Act was promulgated in 1969 to deal with the problem. Although, vis-à-vis the Private College Act of 1969, private institution could provide educational service, the government imposed rigid requirement and enforced strict control in overall aspect of the private HEIs.

Concerning innovative changes, the establishment of two open universities: Ramkhamhaeng University (RU) and Sukhothai Thammathirat University (STOU) in 1971 and 1979 respectively was the most important and innovative development. In contrast to other HEIs, Open University accepted high school graduates without entrance examination and required no class attendance. Although, both RU and STOU were modeled after the British Open University, there was some dissimilarity between these two open universities (Watson, 1981). For example, RU was concerned more with open access for younger students. The objective was to react to rapid increase in demand for HE by providing an effective and economical way, while STOU was much closer to the open university model in term of access for students from all ages, all walks of life and from different locations throughout the country. Besides, STOU made use of correspondence courses, radio and TV programs, community resources and local study centers, RU teaching of RU was to be done largely by CCTV, thus making it possible for more students per lectures to be enrolled in class.

Moreover, as a result of university students uprising in 1973 in resisting the dictatorship of the military government and to generically call for more democratic expansions, the strict state-control on universities' administration was undermined. Afterward, the opportunity to access free education, particularly at the HE level, was enlarged by the new government with a new National Education Act of 1973 which heralded an exponential growth of universities in Thailand.

2.1.3 The Period of Globalization (1990-1996)

During early and mid1990s, Thailand had been challenged by globalization and the pressures towards internationalization. To deal with the pressures resulted from globalization, countries around the world initiated to reform their education system, particular in HE level, for the reason that HE had made essential contributions to enhance scientific knowledge that led to technological developments in critical areas such as transportation and communications, the areas representing the core of globalization accelerants (Ratananukul, 2009, p. 4). Moreover, HE directly promoted the market competitiveness of each country in a context of globalization by providing the capacity of innovation through training higher educated people. Countries which were well endowed with highly educated human resource could progress faster, and those countries in which their HE system was reasonably developed could expand at a fast rate (Varghese, 2004, p. 8). Therefore, policy makers and educators in each country have to consider how to reform their HE system and for prepare highly trained graduates to more effectively cope with the challenges in the new era.

For Thailand, in the period of globalization, several efforts in HE reform had been taken place. The *first* attempt in adapting to the challenges of globalization was in 1990 when the Ministry of University Affairs (MUA) organized the first 15-year HE plan, covering 1990-2004 (The First Long Range Plan for Higher Education) to outline 15 years of HE reform. With this plan, public HEIs should be transformed to be autonomy institution by debureaucratization and increasing marketization. The plan stipulated that future public universities being established must be autonomous from the beginning whereas existing public universities should be incorporated within 10 years (Kirtikara, 2002). In accordance with this principle, three new universities were established: Suranaree University (SUT), Wailaluck University (WU), and Mae Fah Luang University (MFU). Soon after the plan announced, there was an attempt to overhaul 16 public universities as autonomous universities but it was not successful because many academics, university administrators, and the public did not take the nature and benefits of autonomous universities into account. At that time, there were no more attempts that have been made, except when King Mongkut's University Technology Thonburi (KMUTT) had decided to pursue the incorporation path and became an autonomous university in March 1998. KMUTT is viewed as the first public university that has been transformed from a university under the Civil Services to become an autonomous public university (Kirtikara, 2002).

The second attempt was in 1994 when Ministry of University Affairs (MUA) and the council of University President of Thailand held the conference to call for a quality assessment of Thai HEIs. The guidelines for all universities to conduct self-evaluation to promote instruction and improve the academic learning environment were announced by MUA on July 8, 1996. Apart from these guidelines, there were no major policy implementations regarding quality assessment (Sae-Lao, 2013).

The third attempt arose from the concern of Thai private sector on the capacity of education system as a main responsibility body to cope with globalization influences. For example, the commission on Thai Education in the Globalization Era was established, supported by Thai Farmers Bank. The commission composed of leading academics, public intellectuals, and business sector for the purpose of brain storming to find out suitable ways in educational reform. Ultimately, the commission released a report titled "Thai Education in the Era of Globalization: Vision of a Learning Society" in 1996. The report recommended a radical reform of the entire Thai education system, and presented the important obstacles to achieve better education quality: rigid bureaucratic, centralized planning, and lack of social participation. In line with the report, the state and its bureaucracy were framed as impediments to improve education quality, and urgently required de-centralization, de-bureaucratization, and greater autonomy of education management at every education level, especially higher education (Ketudat, 1996). Moreover, many leading academics and public figures outwardly criticized the state and called for empowerment of the people. In the report, the privatization of public sector toward greater efficiency and accountability was also required. Certainly, in case of HE system, the report also emphasized on the policy of transforming public universities to be autonomous which was more like privately running business company for the purpose of improving quality of institutions. Even though, there were various demands for reform, no implementation was really enacted because there was a resistance to the university autonomy policy from various HE system stakeholders.

2.1.4 The Period of Economic Crisis of 1997 and its Aftermath (1997-2010)

The economic crisis in Thailand started in July 1997 when the Thai baht is estimated to have lost 36 % of its value against the U.S. dollar between 1997 and 1998. The demonstration of the crisis in the financial market in a form of currency devaluation was quickly followed by rapid contraction of overall economic activity, employment declining and real earning (World Bank, 1999). As a result, the GDP growth rate fell from over 8 %in 1997 to somewhere between -8 % in 1998. In addition, banks harshly confronted non-performance loans to the turn of 40 %. Moreover, the crisis put fiscal pressure on the government. It raised budget deficits due to tax base reducing and import expenditure increasing from currency devaluation. The central government debts as share of GDP augmented from 6.3 %in 1997 to 20.6 %in 1999 (ADB, 2000). Also, by financial bailout, the debts had achieved 35-50 %of GDP (World Bank, 1999).

After the country was confronted with the most severe economic crisis in its modern history, Thai HE system embarked on its radical reform that was the most inclusive and extensive in recent history. Thai education system, particularly in HE level, was firstly blamed as it failed to prevent the crisis. It was also put forward as a mechanism to restore the collapse of the country's economy, to lay a strong foundation to enhance the country's competitiveness in the era of globalization, and to promote the wellbeing of Thai people in every aspect (Phaktanakul, 2015). Hence, there was a requirement for new design of education that put more emphasis on the cultivation of knowledge along with morality in learners at all levels of its system. Consequently, in 1999 the National Education Act (NEA) was promulgated. This Act served as a basis for the country education reform, including higher education (Kirtikara, 2001). According to the Act, education should be based on the principle that all learners are capable of learning and self-development. The teaching-learning process shall aim at enabling learners to develop themselves at their own pace and to the best of their potential. Such principle of learning reform is applied to not only basic education but also higher education (Sangnapaboworn, 2003).

Moreover, as a result of adoption the IMF-led assistance package, Thai government needed to reduce fiscal spending, and deploy tightened monetary policy. This certainly had an impact on Thai education system. In 1998, the budget for education decreased for the first time by 1.4 %, although there was an attempt to maintain this budget. Regarding HE sector, the budget declined from 36,726 million baths in 1997 to 32,901 million baths in 1998. Due to decreasing in government financial support and no longer able to rely only on government funding, HEIs needed to diversify financial resource of revenues to overcome the shortage of their revenues which once greatly subsidized by the government.

In addition, with the suggestion of Asian Development Bank (ADB), the government decided to reform governance arrangement on HE system by execution of institutional-autonomy policy which endeavored to lower the heavy burden of its financial subsidy for public HEIs and to alleviate the rigid structure of Thai bureaucracy within the HEIs. Under the institutional-autonomy policy, HEIs were freed from the government's bureaucratic restriction on HEIs' financial and administrative autonomy, due to its rigid administrative structure towards the rapid changes created from local needs and the forces of globalization. For example, the government would delegate all HEIs the authority and responsibility to manage the entire non-salary component of the current budget. Besides, the autonomous HEIs were in a position to freely recruit both academic and supporting staff based on their own personnel management system and these staff will no longer be civil servants.

Consequently, in 1997, there were two Buddhist universities changing their status to autonomous ones: Maha Mongkut Rajavidhayalaya University and Maha Chulalongkorn Rajavidhayalaya University. After that, King Mongkut‘s University of Technology Thonburi (KMUTT) was upgraded from the status of Technology College to the status of university and decided to make transition to become an autonomous university in 1998. KMUTT is publicly regarded as the first existing public university making the transition to become autonomous. Additionally, two more autonomous universities were established: Walailak University (WU) and Mae Fah Luang University (MFU) in 1998 and 1999, respectively.

Furthermore, a quality assurance system in HE level both internal and external was systematically established in order to ensure higher education institutions' responsibility, accountability, and transparency. Internal Quality Assurance (IQA) was viewed as part of educational administration which must be performed continuously. In 2002, MUA announced system, criteria, and internal quality assurance system on HEIs as the operation guideline. The announcement specified that the MUA encouraged and supported HEIs to start up efficient and effective internal quality assurance systems that were in line with their missions. Annual reports needed to be prepared and submitted to authority organizations and agencies concerned, and made available to public for the purpose of improving educational quality and standard, and providing the basis for External Quality Assurance (EQA). On the contrary, an Office for National Education Standards and Quality Assessment (ONESQA) was responsible for EQA development on criteria and methods of external evaluation, conducting evaluations of educational achievement in order to assess the quality of HEIs. All educational institutions would receive external quality evaluations at least once in every five years and the last exercise and the results of the evaluation must be submitted to the relevant agencies and made available to the public.

2.2 The Governance Structure of Thai Higher Education System

As a result of the National Education Act promulgation in 1999 and the bureaucratic reform in 2003, Thai HE system has dramatically changed, particularly in term of governance system. Before 2003, administration of the system was primarily under the jurisdiction of two ministries: the Ministry of Education (MOE) and the Ministry of University Affairs (MUA). MOE was mainly responsible for administering education at diploma and undergrads levels including vocational & technical, teacher training, physical, dramatic and fine arts education. HEIs under the control of MOE were Rajabhat Institutes, Rajamangaly institutes of technology and public and private vocational colleges. Alternatively, MUA directed and coordinated colleges, institutes and universities, for both public and private types, which provided education at degree level. It was also responsible for formulating HE policy in accordance with the national education development plan under the supervision of National Education Council (NEC). In addition, MUA took the responsibilities for setting up curricula standard and recommending areas for public funding allocations.

In the year of 2003, there was a merging of three agencies playing crucial role in Thai HE system: MOE, MUA, and NEC, to form new single MOE with a new administrative structure. The new MOE was empowered to encourage and supervise all levels and types of education, no exception for HE level. This event caused important changes in educational administration of Thai HE system. According to Article 10 of the Ministry of Education Regulatory Act 2003, central administrative bodies of the new MOE consist of six offices as follows: 1) Office of the Minister, 2) Office of the Permanent Secretary (OPS), 3) Office of the Education Council (OEC), 4) Office of the Basic Education Commission (OBEC), 5) Office of the Vocational Education Commission (OVEC), and 6) Office of the Higher Education Commission (OHEC). All agencies except 1) has a legal status as a juristic person. Though administratively, each is equivalent to a departmental level, its Chief Executive Officer (CEO) reports directly to the Minister of Education. Apart from the merging of three education-related agencies to create the new MOE, there was an attempt to transfer the power from government to HEIs under the supervision of OHEC, with the purpose to promote administrative autonomy and encourage local-decision making eventually leading to increasing in overall efficiency of the HE system.

Within the new MOE, three agencies are directly responsible for HE service and provision: the OHEC, the OVEC, and the Office of the Private Education Commission (OPEC), functioning under the OPS. Apart from the three agencies, there were other ministries involving in offering HE specific fields and managing institutions of higher learning based on their expertise and special need, as shown in Figure 2.1. However, OHEC has accommodated the majority of student enrollment and played the lead role in controlling HEIs and student enrollment. Therefore, this study emphasizes on the HEIs which are under the authority of the OHEC.

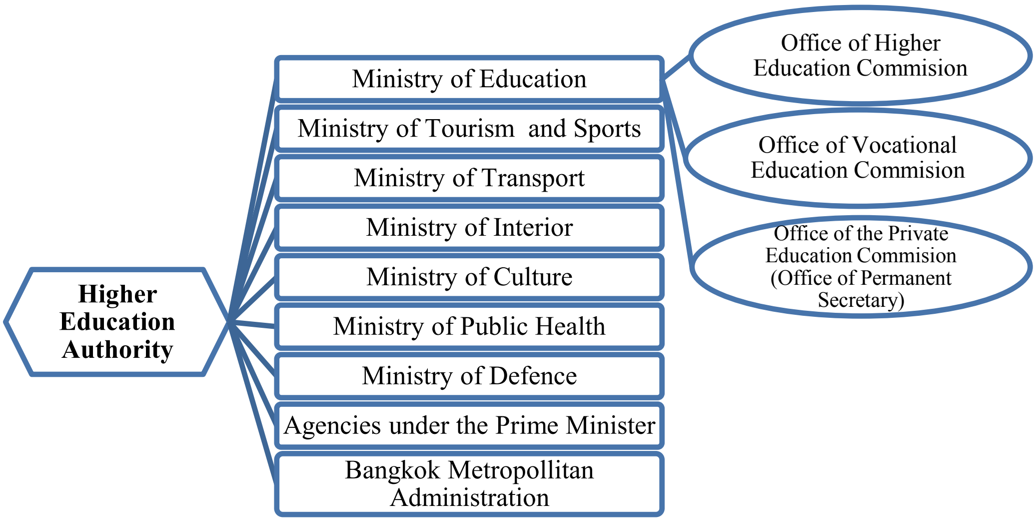


Figure 2.1 Organizational Structure of Higher Education Governance in Thailand
Source: Adapted from Office of the Education Council, 2007.

OHEC is directed by the Commission on Higher Education (CHE) which has the authority in administering all public & autonomous HEIs and overseeing the performance of private HEIs. The Commission is governed by a board with diversity of membership (Figure 2.2). Members of the board come from relevant agencies such as representatives from private sectors, local administration, professional associations, and qualified members. According to Article 16 of the Ministry of Education Regulation Act, the CHE Board has the power to formulate policies and issue regulations in accordance with the National Economic and Social Development Plan, and National Education Plan. Moreover, the Board has to set standards while providing resources as well as to carry out follow-up activities, inspections and evaluations of HE management on the basic of freedom and excellence of each individual degree-granting institution. In addition, the board has to consider issuing regulations, criteria, and official orders deem necessary. The CHE Board is also empowered to provide recommendation and consultation to the Minister of Education or the Ministry council. Other authorities of the Board are prescribed by law or as command by the Minister of Education. Furthermore, it has been given the power to propose block grants for HEIs, either public or autonomous institutions.

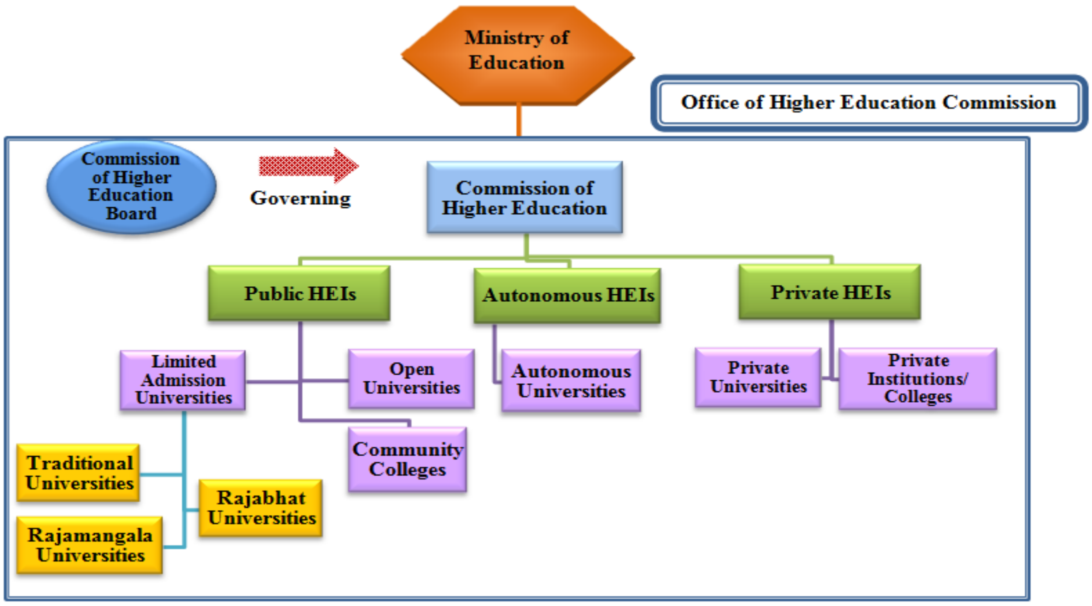


Figure 2.2 Governance structure of Higher Education Institution under The OHEC

Source: Sumate Yamnoon, 2008.

As governed by the CHE Board, CHE has the authority to manage HE provision and promote HE development on the basis of academic freedom and excellence. Its mandates are follows: 1) formulate policy recommendations, standards, development plans, and handle international cooperation; 2) devise criteria and guidelines for resources allocation, establishment of HEIs, and provide financial support; 3) coordinate and promote human resources development and student capabilities, including handicapped, disadvantaged, and talented students in HEIs as well as coordinate and promote research activities for the generation of new knowledge to support the national development; 4) provide recommendations on HEIs establishment, dissolution, amalgamation, upgrading and closing down; 5) monitor, inspect, and evaluate outcomes of HE management as assigned by the CHE, and compile data and information on HE; 6) serve as secretariat to the CHE Board; and 7) perform other functions as prescribed by and to carry out other tasks as assigned by the Minister of Education or the Council of Ministers. Although, CHE has the power to manage the system, its role is only a channel for collaboration between the government and HEIs on the basic of coordination rather than control, with no interference in internal affairs (Yossomsakdi, 2003).

All HEIs under the jurisdiction of CHE have their own act which empowers the HEIs' Council to function as governing bodies directly responsible for their policy and the administration. The council is entitled to grant degrees, graduate certificates, diplomas and certificates at the institutional level. Moreover it involves in almost every aspects of HEIs including: the selection of the president, deans, and directors; the determination of the major goals of the HEIs, approval of policy planning and regulating the HEIs' affairs (OHEC, history of HE in Thailand).

Generally, the number of HEIs' council members varies from one institute to another. Members of the council consist of a distinguished figure (politician or scholar) as the council chairperson, the president, deans, institutions directors, representative from faculties, and other qualified persons not salaried by the HEIs such as scholars from other HEIs, senior government officials, successful businessman, and politicians. Importantly, it needs to be noted that no representatives of the student senate or other student organizations are included in HEIs' council. The HEIs' council serves at minimum one term of office, or at maximum of two terms of office, each term equals to two years. However, there are some differences in characteristics and responsibilities of HEIs' council across HEIs' types, as shown in Table 2.1.

Table 2.1 Characteristic and Responsibilities of HEIs' Council across HEIs' Type

Characteristics	Public HEIs	Autonomous HEIs	Private HEIs
• **Chairperson of HEIs' council**	Appointed by His Majesty the King	Appointed by His Majesty the King	Proposed by licensee & appointed by Minister of Education
• **Members HEIs' council**	1) Qualified members from persons outside the HEIs appointed by His Majesty the King 2) Ex officio member such as University president, Chairman of University Faculty Council, Chairman of University Operation Promotion Board, government agencies' CEO 3) Members selected from: (1) Vice Presidents (2) Dean, institutes/ bureau /center directors (3) University Faculties 4) Secretary of the council selected by Vice President	1) Qualified member from person outside the HEIs appointed by His Majesty King 2) Ex officio member such as University president, Chairman of University Faculty Council, Chairman of University Operation Promotion Board, government agencies' CEO 3) Member selected from: (1) Vice Presidents (2) Dean, institute/ bureau /center directors (3) University Faculties 4) Qualify Member selected from external expert approved by Ministers of Education & appointed by His Majesty King	1) Qualified member proposed by the licensee whereby at least one is the representative from academic staff & appointed by Minister of Education 2) Qualified member selected by the Ministry from qualified members list as proposed by the CHE & appointed by Minister of Education 3) President as ex officio member

Table 2.1 (Continued)

Characteristics	Public HEIs	Autonomous HEIs	Private HEIs
		5) Secretary of the council selected by Vice President	
• **Responsibilities**	Public HEIs	Autonomous HEIs	Private HEIs
• **Policy formulation**	√	√	√
• **Quality& Standard supervision**	√	√	√
• **Regulations set up**	Authorized for personnel administration to the extent approved by CHE Board	Fully authorized for personnel & financial administration & investment	Fully authorized for personnel & financial administration & investment
• **Monitoring & Evaluation**	√	√	√

Source: Sumate Yamnoon, 2008.

At an institutions level, the president, as the chief executive administrator, directs institutions under the policies generated by HEIs' Council (see Figure 2.3). To support in operating HEIs which specific areas such as administrative, academic, international, and student affairs, the president may appoint several vice presidents as assistants. Regarding academic matters, the president directs institutions through faculty deans and institutions/bureau/center directors. Whereas other administrative matters was managed through the related vice president. Apart from the HEIs' Council, there are two advisory bodies, i.e. Dean's Council and Faculty Senate which also take part in governing the HEIs.

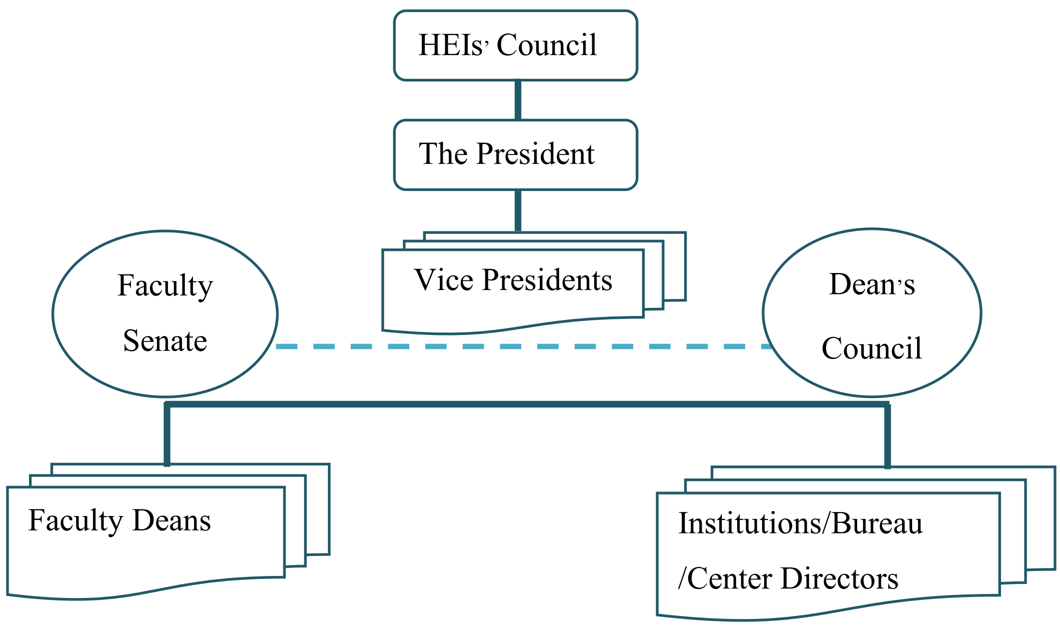


Figure 2.3 Institutional Governance of Higher Education Institutions in Thailand
Source: Adapted from Office of the Education Council, 1999.

Although, there are many similarities of governance structure in each type of HEIs, in some aspects such as degree of autonomy, government regulation and financial support, there exist significant, as detailed below.

Public HEIs: Public HEIs hold status of governmental units which have autonomy in academic administration through the HEIs' council approval. However, they have to comply with the bureaucratic system in financial and personnel administration. As a government unit, public HEIs are allocated annual funds from the Bureau of the Budget (BOB) and audited by the Comptroller General's Department of the Ministry of Finance. HEIs' presidents occupy a position equivalent to director-general, i.e. the chief executive officer at a department level.

Autonomous HEIs: Autonomous HEIs are an innovative type of public institutions established with the purpose of eliminating the conventional bureaucratic system embedded in all government agencies and promoting flexibility and administration independence for each public HEI. These institutions are self-governing with full autonomy. They have their own administrative structure and budget system which allows for decision making on administrative and management matters of the institutions including academic, financial, personnel, and other management systems to be handled by institutions themselves, under the delegated authority of HEIs' council, instead of the central government approval. Even though these HEIs operate outside the government bureaucracy, they are still government-supervised agencies which receive regular budget allocation from the government, in the form of block grants which are considered as the universities own income. Moreover, the government has the power to evaluate and assure the standard and performance of autonomous HEIs according to the policy and standard of HE system. The government also has the authority to audit their accounts and assets through the Office of the Auditor General of Thailand.

Private HEIs: In the same way as public HEIs, private HEIs have their own council which is the administrative body responsible for general functioning of the institution and organizing of its internal administrative structure. They have full autonomy in academic, financial and personnel administration under the supervision of their own council in accordance with the Private Higher Education Act of 2003. Private HEIs have enjoyed certain autonomy and authority to manage their institutions with periodic performance review conducted by the OHEC. However, government has defined more restrictive holistic monitoring and evaluation mechanism to oversee private HEIs more than it does to the public HEIs. Private HEIs are unable to receive national budget support from the government and their financial support for institutional operation comes from their own revenue and licensee. CHE is responsible for scrutinizing and proposing policies, development plans and educational standards in a more appropriate manner that more effectively ensures secured development and enhances the expansion of private HEIs administration.

2.3 Structure of Thai Higher Education System

As a result of HE reforms promoted by the National Education Act of 1999, HE in Thailand has been divided into two levels of lower than degree level and degree level, as shown in Figure 2.4 which exhibits that after competing secondary education, students can go for HE through a vocational & technical track or a more general academic track.

After competing secondary education, students can go for HE through a vocational & technical track or a more general academic track. To attain diploma in vocational & technical, students must complete a lower vocational education or a general academic education. However, the main portion of students choosing for diploma level is the ones who have gained vocational certificate. The main purpose of vocation & technical diploma courses is to provide students with knowledge and vocational & technical skills at a middle level required for enhancing enterprise productivity and profitability as well as creating national productivity and wealth. For further study, vocational & technical diploma holders have an option of pursuing two additional years of courses to achieve a Bachelor’s degree, enabling students to cross over from a diploma to degree level.

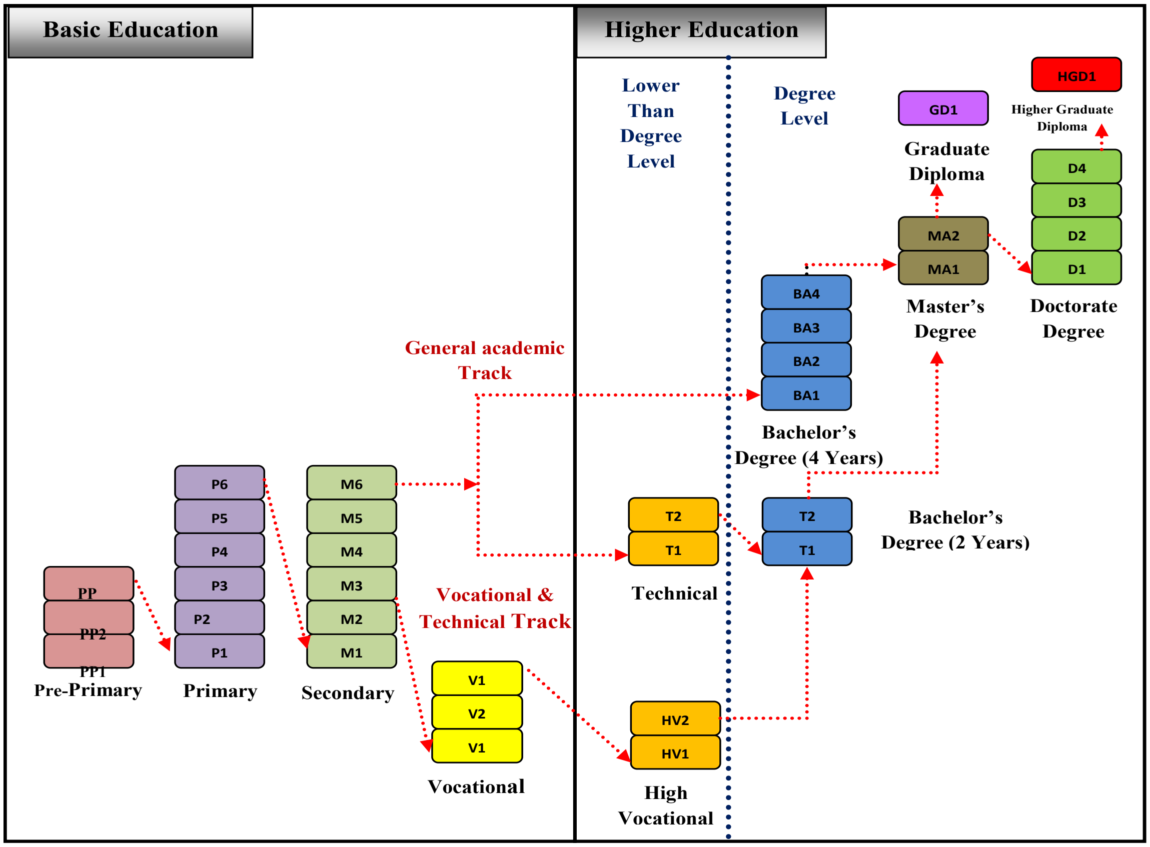


Figure 2.4 Structural of Thai Education System

Source: Adapted from Office of Educational Council, 2007.

Regarding degree level, the degree can be divided into 2 categories: undergraduate and graduate degree. Most undergraduate courses focus on providing a higher level of knowledge and skills in various disciplines to undergraduate students, especially the ability to apply theories to practices, to initiate both academic and professional development, to create and disseminate knowledge, and to participate in national development. Admission to undergraduate degrees has usually been based on the completion of upper secondary education (general or vocational) and the results obtained on the Joint Higher Education Examination. Generally, the standard duration of study for most undergraduate degrees are four years, although architecture, art, graphic art, pharmacy, medicine, dentistry, and veterinary medicine all require more years of study.

In case of graduate degrees, in-depth knowledge and skills to strive for academic progress and excellence, especially in studies, researches, and developments of knowledge and technology on different fields of study is provided in Master degree study while new knowledge or the adaptation, application and interpretation of existing knowledge is cultivated in Doctoral degree study. Master degrees typically involve one to two years of full-time study whereas doctoral degrees are usually completed over three or four years of full-time study.

HE in Thailand is provided by a large number and a wide variety of institutions according to their background and strength in different disciplines e.g. public universities with limited admission, open universities, autonomous universities, Rajabhat universities, Rajamangala universities, private universities, community colleges, public vocational colleges, and private colleges. Positively, this implies that there are greatly varieties in delivering HE, but, on the other hand, there are challenges for administration to manage quality and maintain the standard. These institutions, except for public and private colleges, offer programs of studies in bachelor's degrees and master's degrees, as well as doctorate degrees. Alternatively, most of public and private colleges offer degrees at lower levels or diploma levels with two years course in vocational and technical education.

In 2013, there were 691 HEIs providing HE studies, under the authority of various agencies with more than two million students, as shown in Table 2.2.

Table 2.2 Number of HEIs and Students in HE System by Education Levels, 2013

Agency	No. of Institutions	Number of Students				
		Lower than Bachelor Degree	Bachelor Degree	Higher Than Bachelor Degree	Total	%
Department of Education Bangkok Metropolitan administration	3	-	1,287	-	1,287	0.05
Ministry of Defense	18	437	2,765	106	3,308	0.14
Ministry of Tourism and Sport	18	-	18,591	-	18,591	0.77
Ministry of Public Health	20	2,954	15,499	-	18,453	0.76
Royal Thai Police	12	-	1,117	-	1,117	0.05
Ministry of Transport	2	340	2,201	40	2,581	0.11
Ministry of Culture	10	157	-	-	157	0.01
Banditpatanasilpa Institute	6	-	3,374	-	3,374	0.14
Depart of Local Administration	12	118	-	-	118	0.00
Office of the Private Education Commission	-	84,112	-	-	84,112	3.48
Office of the Vocational Education Commission	421	209,189	204	-	209,393	8.66
Office of the Higher Education Commission	169	18,777	1,825,700	229,611	2,074,088	85.83
Total	691	316,084	1,870,738	229,757	2,416,579	100.00

Source: Ministry of Education, 2015.
Office of Higher Education Commission, 2015a.

From Table 2.2, HEIs authorized by the Office of the Higher Education Commission (OHEC) is the main provider of Thai HE system. As can be seen, over 80 % of students pursuing HE enroll in these HEIs, particularly in the degree level, while in the lower than degree level, the predominant HEIs are under control of the Office of the Vocational Education Commission (OVEC). The figures in Table 2.2 also reveal that there existed two hundred thousand students or about 8.66 % of students, registering in vocational and technical colleges under OVEC.

To be specific, as of 2013, there have been 172 HEIs under the OHEC, which encompass about two million students and over fifty thousand academic staffs. This is a dramatic expansion compared to 78 HEIs in 2002 when Rajabhat and Rajamangala universities were not yet under the control of the Ministry of Universities Affairs (Changed to the OHEC in 2003). According to their establishment legislation as follows, there were 16 public universities (including 14 limited admission universities and 2 open admission universities), 16 autonomous universities, 40 Rajabhat Universities, 9 Rajamangala Universities of Technology, 19 community colleges. On the other hand, the 71 private HEIs consists of 39 private universities and 32 private colleges/institutions (Table 2.3). Although, there is not much different in terms of institute numbers (102 public versus 72 private institutions), Thai HE system is dominated by public sector. There are 85.67 % of students registering in public HEIs, while private have a share only 14.33 %. From Table 3, Rajabhat universities have the highest number of student enrollment, about 27.34 % of students pursuing HE study. Open universities consisting of only two institutions but having the second highest enrollment of student, which is 21.26 %. This is followed by limited admission universities which has 15.63 % of students. As regard to the number of instructors, autonomous universities have the largest share with 33.43 % followed by Limited admission universities and Rajabhat universities with 21.20 and 19.57, respectively. Interestingly, Rajabhat universities and Open universities which are the main providers of HE with almost 50 % of student enrollments have only around 20 % of instructors' share, as shown in Table 2.3. These situation reveal the imperative disparity in HE system. The student-instructor ratios can range from 17.10 in Autonomous universities to 322.00 in open universities.

Table 2.3 Number of HEIs under the OHEC, Enrollments, and Instructors, 2013

	No. of Institutions	Students	Instructors	Student-Instructor Ratios
Public HEIs				
Public Universities	16	792,082 (36.89%)	12,291 (23.87%)	64.44
*** Limited admission Universities**	14	335,584 (15.63%)	10,916 (21.20%)	30.74
*** Open Universities**	2	456,498 (21.26%)	1,375 (2.67%)	332.00
Autonomous Universities	16	294,372 (13.71%)	17,211 (33.43%)	17.10
Rajabhat Universities	40	587,074 (27.34%)	10,176 (19.57%)	58.29
Rajamangala Universities of Technology	9	151,188 (7.04%)	5,241 (10.18%)	28.85
Community Colleges	20	14,886 (0.69%)	143 (0.28%)	104.10
Total(Public HEIs)	101	1,839,602 (85.67%)	44,962 (87.33%)	40.91
Private HEIs				
	No. of Institutions	**Students**	**Instructors**	**Student-Instructor Ratios**
Private universities	41	258,678 (12.05%)	5,868 (11.40%)	44.08
Private college/institutions	31	49,147 (2.29%)	655 (1.27%)	75.03
Total(Private HEIs)	72	307,825 (14.33%)	6,523 (12.67%)	47.19
Total	173	2,147,427 (100.00%)	51,485 (100.00%)	41.71

Source: Ministry of Education, 2015.
Office of Higher Education Commission, 2015a.

Concerning distribution of Higher Education Institutions by region, enrollment in HE also depict some inequality in its system. Most of Thai HEIs are intensely located in Bangkok and central area of Thailand even though there has been a recent expansion of education access at a provincial level. As depicted in Figure 25, 49 % of Thai HEIs are located in Bangkok and the central area of Thailand (with 86 institutions: 44 HEIs in Bangkok and 42 HEIs in the Central). In the northeast and north area, there are 32 (19 %) and 10 (14 %) HEIs, respectively. At 5 % (with 8 HEIs), the proportion of HEIs in the east area is the smallest.

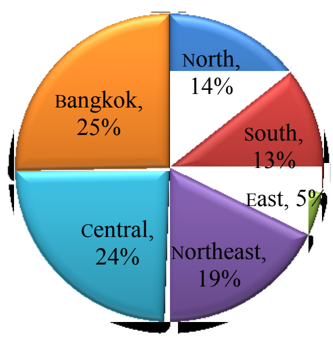
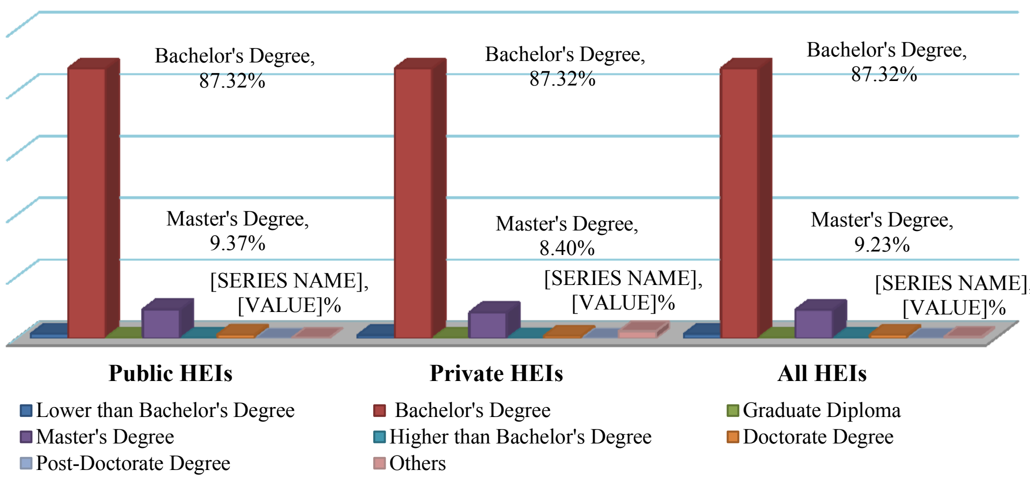


Figure 2.5 Distribution of Higher Education Institutions by Region, 2014

Source: Ministry of Education, 2015.

Office of Higher Education Commission, 2015a.

Besides, Thai HE system confronts a severe gap between undergraduate and graduates education. There is a small share of students enroll in master degree programs (9.23 %) and even fewer in doctorate ones (1.18 %), as depicted in Figure 2.6 (a). Interestingly, the main providers of graduate study (higher than Bachelor's degree) are open universities with the shares of 27.47 %, followed by limited admission universities with the shares of 24.86 %, as shown in Figure 2.6 (b) while Rajabhat universities are the dominant provider in bachelor degree study, as their share is 30.00 %, followed by open universities of 20.84 % share.



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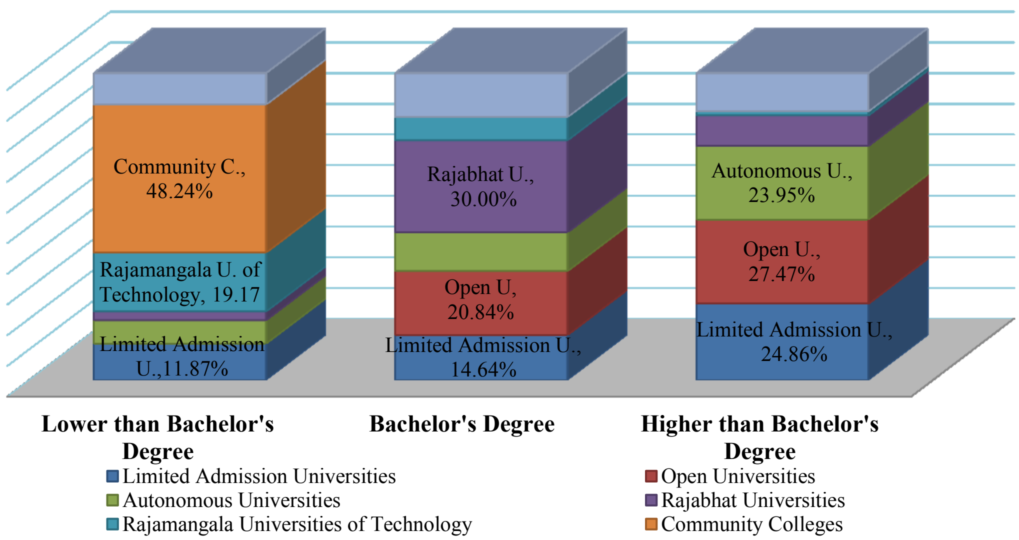


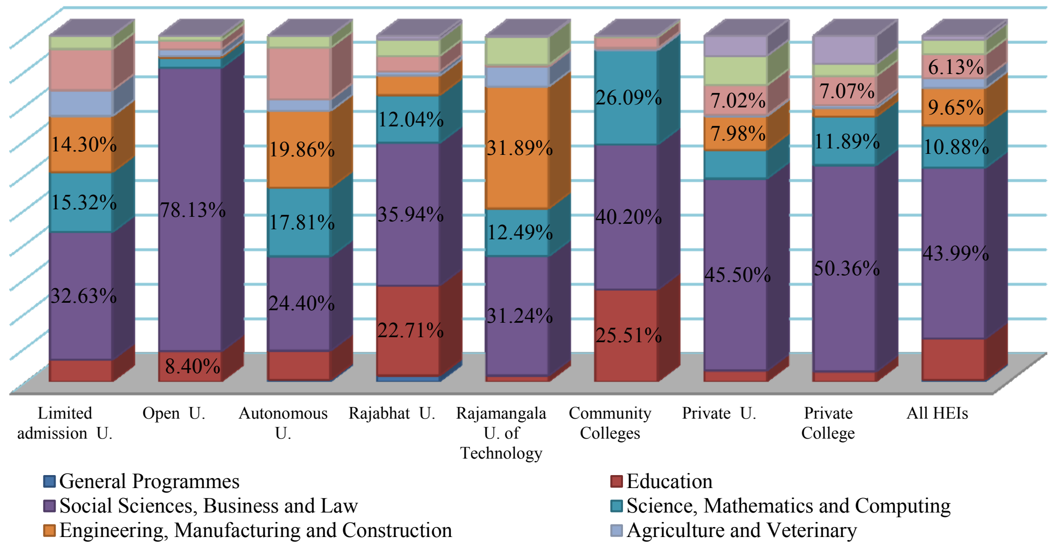
(b)

Figure 2.6 Percentage of Student Enrollment in HEIs by HEIs Type and Study Level, 2013

Source: Ministry of Education, 2015.

Office of Higher Education Commission, 2015a.

Moreover, among the enrollment in HEIs as depicted in Figure 2.7 (a), nearly a half of students are enrolled in Social sciences, Business and Law programs whereas the needs are clearly elsewhere. These fields of study are much more dominant in Thailand, at 43.99 % of all enrollments compared to 20.53 % of all enrollments for Science, Mathematics, and Computing; and Engineering, Manufacturing, and Construction. Enrollments in Health and Welfares programs are quite small, at 6.13 %. As regard to enrollment in Social sciences & Business & Law programs, open universities have the largest share at 37.67 %, followed by Rajabhat universities and private universities at 22.33 and 12.46 %, respectively (Figure 2.7 (b)). Surprisingly, Rajabhat is dominant in providing Sciences, Mathematics & Computing programs. Its share is 30.26 % while in the field of Engineering, Manufacturing, and Construction; and Health and Welfare, autonomous universities have the largest shares at 28.22 and 30.00 %, respectively.



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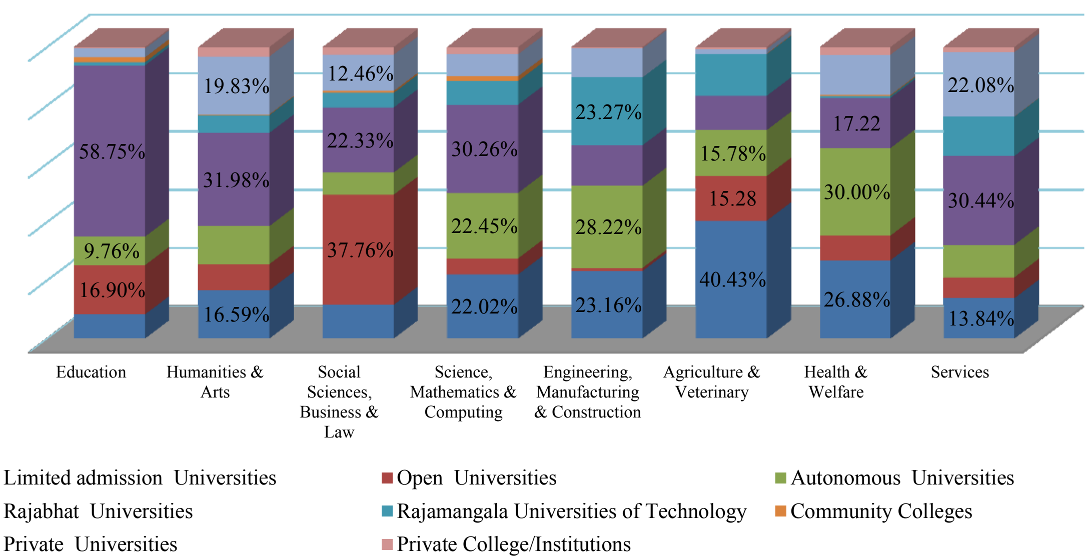
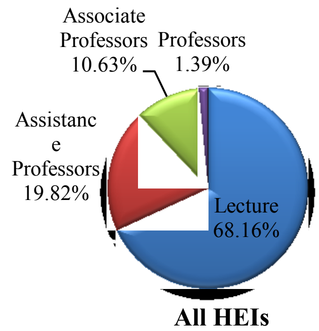


(b)

Figure 2.7 Percentage of Student Enrollment in HEIs, By HEIs Type and Study Field

Source: Office of Higher Education Commission, 2015a.

As for academic staff in HEIs under OHEC in 2013, there is 50,964 academic staff. Of these numbers, 87.53 % are in public HEIs, and the rest is in private HEIs. The distribution of academic staffs' academic position reveal some imbalance, as shown in Figure 2.8 (a). Overall, there are relatively high proportion of lecturer (68.16 %) and the small share of professors (1.39 %). Similarly, each type of HEIs follows this pattern. Concerning the position of full Professors, autonomous universities have the largest share with 77.82 % of academic staff assigned full professor. Limited admission universities are second with the share of 13.72 % (Figure 2.8 (b)). In addition, the majority of academic staffs in both public and private HEIs in Thailand hold graduate degrees, with over 90 % holding at least Master Degrees, as shown in Figure 2.9 (a). The proportion of academic staffs' degree-Bachelor: Master: Ph.D-in public HEIs is 7: 50: 43 while in private HEIs is 10: 67: 23. Considering the shares of academic staffs with doctorate degrees, autonomous universities have the highest share with 54.04 %, followed by 25.48 share of limited admission universities (Figure 2.9 (b)).



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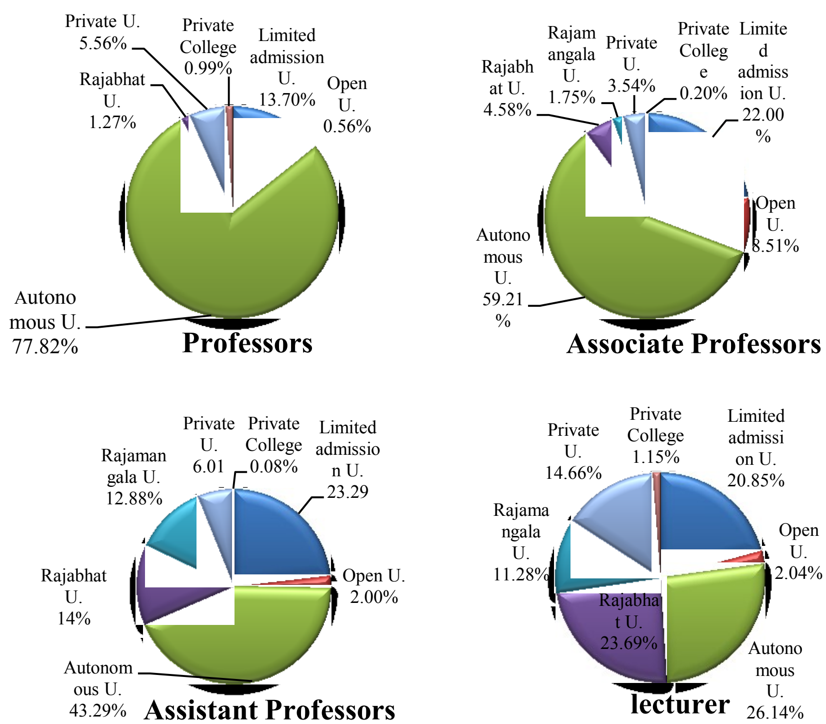
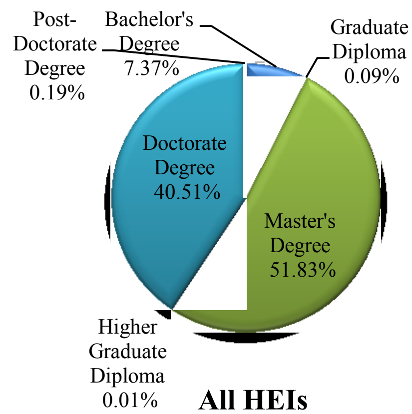


(b)

Figure 2.8 Percentage of Academic Staff by Academic Position and HEIs Type, 2013

Source: Office of Higher Education Commission, 2015a



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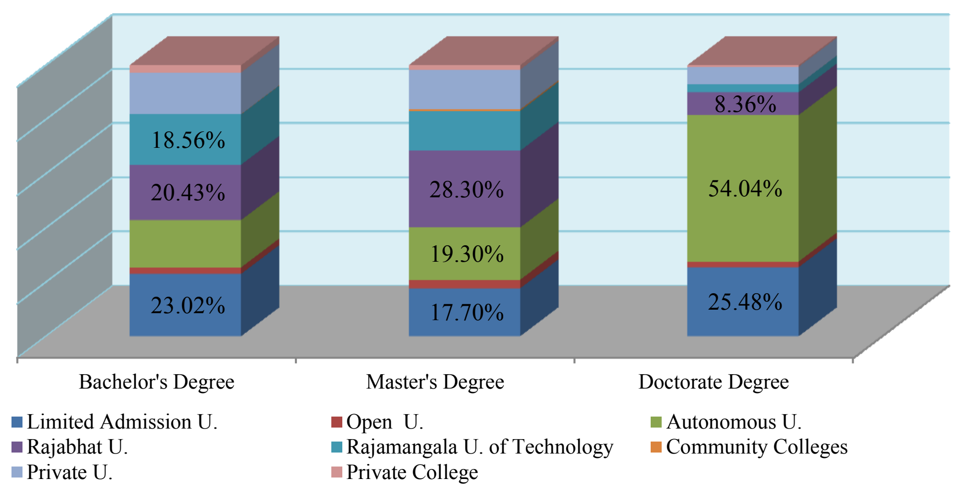


(b)

Figure 2.9 Percentage of Academic Staff by Educational Level and HEIs Type, 2013

Source: Office of Higher Education Commission, 2015a.

2.4 Quality Assurance in Thai Higher Education System

In 1999 after the promulgation of National Education Act, the first official implementation of HE Quality Assurance (QA hereafter) system in Thailand occurred in order to coincide with the global education policy trends on the quality of HE provision (Sae-Lao, 2013). The National Education Act of 1999 (2nd Amendment in 2002) has expressed aims and rationale for education management emphasizing on quality and standards, as detailed in chapter 6: Standards and Education Quality Assurance. In order to guarantee the quality of HE system, the set of standards is established as follows: the HE Standards, the HEIs Standards together with other relevant standards and criteria, and the Thai Qualification Framework for HE.

CHE, in regards to the HE standards, has developed the HE standards by using the national education standards as a development framework. The standards describe purposes and principles of education administration among HEIs. These standards consist of 3 sub-standards: 1) the standard for the quality of graduates, 2) the standard for HE administration, and 3) the standard for establishing and developing a knowledge-based and learning-based Society. They are respectively related to 3 national education standards: 1) desirable characteristics of Thai People as citizens and members of the world community, 2) guidelines for education management, and 3) guidelines for creating a learning/knowledge-based Society.

Apart from the HE standard as a primary standard, CHE has also established HEIs standards in 2008 to enhance the development of groups of HEIs with various philosophies, objectives, and missions proceeding effectively and efficiently. The groups of HEIs are: Group A-community colleges, Group B-institutions focusing on undergraduate studies, Group C-specialized institutions (including C1: institutions focusing on graduate studies, C2: institutions focusing on undergraduate studies, and Group D-institutions focusing on advanced research and production of graduates at the graduate studies levels, especially the doctoral level. The HEIs standard composes of 2 main components, i.e. 1) standard for the Capability and Readiness of Education Management, and 2) standard for HEIs Operation. In addition, CHE has devised other relevant standards such as standard criteria for HE curricula, criteria for asking permission to offer and manage degree programs in the distance education system, criteria for designating degree titles, and criteria and guidelines for the assessment of education management quality of off-campus programs. These standards assist HEIs in developing their academic and professional strengths along with enhancing and raising the quality and standards of HE management to meet international standards as well as make the education management flexible and smooth at all levels.

Lastly, in order to guarantee the quality of HE graduates at all educational levels and in all disciplines, the Thai Qualification Framework for Higher Education is formulated in line with the HE Standards. The quality of graduates must meet learning outcome standards that cover at least 5 areas: 1) Morality and Ethics, 2) Knowledge, 3) Intellectual Skills, 4) Interpersonal Skills and Responsibility, and 5) Skills in Quantitative Analysis, Communication, and Information Technology Usage.

According to the National Education Act of 1999 chapter 6 (section 47), assurance in the educational system is comprised namely of two systems: an Internal QA system and an External QA system which are supposed to be a mechanism for maintaining quality and standards of HE system.

2.4.1 Internal Quality Assurance

CHE as the governing authority of HEIs in charge of monitoring, inspection and evaluation of higher education provision plays an important role in encouraging full-fledged QA systems in all public and private HEIs. According to the Ministerial Regulation regarding Systems, Regulation, and Methods for Internal Quality Assurance of 2010, CHE is assigned two duties on internal QA for HE system: 1) introducing regulations or announcing criteria and practices for internal QA to facilitate, support and improve the internal QA processes at HEIs; 2) proposing guidelines for continuing improvement and development of educational quality for institutions by using the results of both internal and external quality assessments.

In order to give a guideline for HEIs, CHE has published a manual for the internal QA in response to the National Education Act of 1999 (2nd Amendment in 2002) and related regulations and standard. It identifies a comprehensive set of educational QA indicators covering 9 quality components, including: 1) philosophy, commitments, objectives and implementation plans; 2) teaching and learning; 3) student development activities; 4) research; 5) academic services to the community; 6) preservation of arts and culture; 7) administration and management; 8) finance and budgeting; and 9) systems and mechanism for quality assurance. HEIs can use these indicators for their internal assessment including input, process, and output/outcome. Besides, the indicators suggested by CHE also include recommended practices and examples of development approaches. Moreover, since the internal QA system is expanded to include quality assessment, inspection, and development, CHE as the parent organizations must monitor and inspect educational quality at least once every three year, and report the results to institutions and disclose them to the public as well (OHEC, 2014).

At an institutions level, HEIs have to establish an internal QA committee, develop and implement the system and mechanism for internal QA, carry out internal quality assessments, and annually report the assessment findings to CHE. All HEIs are required to appoint an internal QA committee in charge of the internal QA system. This committee has the responsibility to develop, administer, and follow-up on the operation of institutions. The committee also has to coordinate with external office to assure that the education administration in all levels is efficient.

Afterward, an efficient system and mechanism for internal QA is developed so as to control, audit, and assess the educational quality to be in line with the policies and principles set by CHE. The established system and mechanism for internal QA in HEIs need to cover all components used to produce graduates which are: 1) curriculum in all majors, 2) faculty members and faculty development system, 3) education media and teaching techniques, 4) library and study resources, 5) other educational equipment, 6) learning environment and academic services, 7) students evaluation and outcome, and 8) other relevant components that each institute considers appropriate. The core standards that HEIs use as the framework for developing the internal QA system and mechanism are the HE Standards. Apart from these HE standards, in case of public HEIs, other standards that HEIs must comply with such as standards criteria of higher education curriculum, standards for the external quality assessment of the Office for National Education Standards and Quality Assurance (ONESQA, 2012) and standards of the Office of Public Sector Development Commission (OPDC). However, HEIs may develop appropriate QA system and mechanism that is in accordance with the level of development in each institution. On the other hand, they may use a generally practiced quality assurance system well known in the national or international level or develop its own QA system. Later, the developed system and mechanism for internal QA is implemented, taking into account as one part of the educational administration process has to perform systematically and continuously. Finally, HEIs have to annually prepare Self-Assessment Report (SAR) that internally assess the educational quality and submit such report to the HEIs' council, OHEC, relevant organizations, and the public, in line with the purpose of the National Education Act of 1999 (2nd Amendment in 2002).

2.4.2 External Quality Assurance

According to the National Education Act of 1999 (2nd Amendment in 2002) section 49, the Office for National Education Standards and Quality Assessment (ONESQA) was established in 2000 as a public organization to perform external QA. The ONESQA is responsible for development of external QA criteria and methods of external evaluation, conducting evaluation of educational achievements to assess quality of all types and levels of educational institution, bearing in mind the objectives, principles and guidelines for each level of education as stipulates in this act. All educational institutions including HEIs shall receive external quality evaluation at least once every five year since the last exercise and the result of the evaluation shall be submitted to the relevant agencies and made available to the general public.

Under the responsibility of ONESQA (2012), external QA is an evaluation of educational management in which the external agencies or individuals examine the quality of educational institutions by collecting and studying the data from SARs of the institution and other report documents by observing, questioning, and interviewing those who are the stakeholders in order to gather the real data from the real situation for the purpose of the institutional assessment. The aim of this assessment is to ensure that educational institutions continuously develop and improve their educational quality and standards.

According to the Manual for Third Round of External Quality Assessment (2011-2015) by ONESQA (ONESQA, 2012), a process of external QA of any educational institutions starts with internal QA so that development and self-improvement plans are made, carried out to improve quality, which is then monitored and tracked, and a system of self-assessment is established. After that, external assessment is conducted through ONESQA (2012) by considering and verifying the results of the institution's internal quality assessment. Thus, internal QA and external QA should be consistent with and proceeded in the same direction because both of them aim to improve standards or expected quality for learners. ONESQA (2012) has outlined the following objectives for external quality assessment.

Since its establishment, ONESQA (2012) has undertaken three rounds of quality assessment. The focus points of each round are different regarding the differences of educational situations and problems. Each round processes different characteristics in terms of principles, objective, unit of analysis, quality standard and indication, criteria for certification, and assessment results as follows.

The first round of assessment happened between 2000 and 2005. It aimed at verifications of the real situations within educational institutions and to encourage all institutions to reveal their self-evaluation report alongside with basic information reflecting their internal QA system, without judging or accrediting the institutions. Moreover, the first round of assessment attempted to underscore the main concept of the National Education Act, which restates that education is a shared responsibility of all stakeholders (Sae-Lao, 2013). As shown in Table 2.4, the assessment framework of the first round composed of 8 quality standards and 28 indicators. As detailed in Table 2.5, different results of the first round assessment of the HE system reveal that there are 91.92 % of HEIs which is considered to be acceptable in term of quality levels (fair, good and very good), while only 47.69 % of HEIs can achieve ONESQA standards at good and very good quality levels. Although the results do not yield desirable outcome as expected, the positive impact of such assessment is the emergence of quality management thinking and a drastic change in educational institutions culture and reaction toward public accountability (Nakornthap, A., 2009).

The second round of assessment was performed during 2006-2010. Even though the principle and objectives of the 2nd quality assessment are quietly similar to the 1st round, there are still several aspects of differences, as depicted in Table 2.4. Firstly, consider to the variation of HEIs based on their philosophy developed for excellence according to their uniqueness and identity, ONESQA has asked HEIs to explicitly declare their emphasis points according to their missions, and distribute the weight to each of their functions accordingly. In line with this purpose, HEIs have been categorized into 4 groups: 1) Producing Graduates and Research Group, 2) Producing Graduates and Social Development Group, 3) Producing Graduates and Development of Arts and Cultures Group, 4) Producing Graduates Group. Secondly, there are smaller number of quality standards and greater number of indicators. In the 2nd round, the quality standards consist of 7 categories with 48 indicators. Moreover, the weight of the standards and indicators are varied by institution group and the specific indicators by their emphasis points. Thirdly, the unit of analysis is different from the 1st round as in the 2nd round the unit of analysis has focused on both institutional and program group levels. These program groups consist of: 1) Health Science, 2) Physical Science, 3) Science, 4) Agriculture, 5) Management, Accounting, and Economics, 6) Education, 7) Humanities and Social Science, 8) Arts and Applied Arts, 9) Interdisciplinary, and 10) Academic Supports (ONESQA, 2012). Finally, in contrast to the 1st round, the 2nd round of assessment provides accreditation to both program and institution levels. Regards 256 HEIs assessed, there are 220 accredited, 10 pending and 6 not being accredited, as shown in Table 2.6.

The 3rd round of assessment began in 2011 and last in 2015. The additional principle of the 3rd round which is different from the previous assessments is placing importance on the characteristics and categories of educational institutions. Moreover, in order to reduce the number of quality standards and indicators, the connection between internal QA and external QA is reconsidered. OHEC, responsible for internal QA, is mandated to focus on the input and process of educational production process while ONESQA, responsible for external QA, is liable for the output and outcome of educational production process. According to ONESQA's published manual on the Third round of external QA (ONESQA, 2012), the quality standards and indicators are reduced to only 6 standards and 18 indicators. The added aims of the 3rd round are to raise the level of HEIs' educational quality standards by scrutinizing products, results, and impacts more than processes and to encourage HEIs to maintain their consistent direction in regards to external and internal quality assessment, including building cooperation and shared goals between higher bodies and relevant agencies in order to link operations with joint quality improvement (Table 2.4). In addition, this new assessment framework also provides an opportunity for each institution to identify indicators which are unique and appropriate to their development environmental.

Table 2.4 The Comparison of Three Round of External QA

	1st Round (2000-2005)	2nd Round (2006-2010)	3rd Round (2011-2015)
Principles	1) Assess to enhance the quality of education, not to judge, not to find faults with, not to reward or punish Conduct assessment with fairness, transparency, and accountability, and evidence-based 2) Emphasize on the promotion and coordination amongst true friends, not to the control 3) Promote partnership in quality assessment and education provision development with all concerned Balance among education freedom and national objectives and principles of education as stipulated by the National Education Act of 1999	1) Assess to enhance the quality of education, not to judge, not to find faults with, not to reward or punish Conduct assessment with fairness, transparency, and accountability, and evidence-based 2) Emphasize on the promotion and coordination amongst true friends, not to the control 3) Promote partnership in quality assessment and education provision development with all concerned Balance among the education freedom and the national objectives and principles of education as stipulated by the National Education Act of 1999	1) Assess to enhance the quality of education, not to judge, not to find faults with, not to reward or punish 2) Conduct assessment with fairness, transparency, and accountability, and evidence-based 3) Emphasize on the promotion and coordination amongst true friends, not to the control 4) Promote partnership in quality assessment and education provision development with all concerned 5) Balance among the education freedom and the national objectives and principles of education as stipulated by the National Education Act of 1999 6) Place importance on the characteristics and categories of educational institutions 7) Reduce the number of quality indicators by taking into account the connection between internal QA and external QA

Table 2.4 (Continued)

	1st Round (2000-2005)	2nd Round (2006-2010)	3rd Round (2011-2015)
			8) Put emphasis on qualitative and quantitative indicators, those that are positive as well as negative.
Objectives	1) To reveal the real situation of educational provision with the institution 2) To access educational quality according to the HE standards and methods established by ONESQA, and to guarantee that these are consistent with QA systems of the HEIs and the relevant higher bodies 3) To obtain the information reflecting the strength and weakness of the institutions and explore best practices 4) To provide guidelines to improvement the institutions and its parent organization 5) To encourage continuous improvement & develop internal QA	1) To validate the real situation of the educational provision within the institutions. 2) To efficiently assess education quality against HE standards, following the guidelines and methods as specified by ONESQA while conforming to the QA system of HEIs and their parent organizations. 3) To identify and collect information about strength and weakness of the institutions, critical success factors, and causes of problems, as well as innovation and good practices. 4) To give recommendations on how to improve and develop the educational quality to the institution and its parent organization.	1) To verify the actual operating conditions at educational institutions 2) To assess educational quality in line with the HE standards and methods established by ONESQA; and to ensure that these are in harmony with the quality assurance systems of HEIs and their relevant higher bodies 3) To obtain information reflecting HEIs' differences showing their distinctive identities as well as success of their operations in accordance with the government's promotional measures 4) To encourage HEIs to continuously develop and improve quality and their internal QA systems 5) To report and publicize quality assessment results and institutions administrative efficiency to relevant organizations and the general public

Table 2.4 (Continued)

	1st Round (2000-2005)	2nd Round (2006-2010)	3rd Round (2011-2015)
	6) To report the results of the quality assessment and standards of the institutions to the concerned organizations and the public	5) To support the institution in its continuous quality development and assurance 6) To report the results of quality assessment and standards of the institutions to the concerned organizations and the public	6) To raise a level of HEIs' educational quality standards by scrutinizing products, results, and impacts more than processes 7) To encourage HEIs in maintaining a consistent direction in regards to external and internal quality assessment 8) To build cooperation and shared goals between higher bodies and relevant agencies in order to link operations with joint quality improvement
Unit of Analysis	Institution	Institution and Disciplinary Group	Institution
Quality Standards/ Indicators	8 Quality Standards with **28** Indicators for all institutions as follows: 1) Quality Graduate Standard including 4 Indicators 2) Learning Standard including 4 Indicators 3) Learning Supports Standard including 5 Indicators	7 Quality Standards with **48** Indicators (39 Common Indicators, 9 Specific Indicators According to HEIs' Group) as follows: 1) Quality Graduates Standard including 6 Common Indicators and 2 Specific Indicators 2) Research and Innovation Standard including 5 Common Indicators and 2 Specific Indicators	6 Quality Standards with **15** Basic Indicators as follows: 1) Quality Graduates Standard including 4 Basic Indicators 2) Research and Innovation Standard including 3 Basic Indicators 3) Academic Service Standard including 2 Basic Indicators

Table 2.4 (Continued)

	1st Round (2000-2005)	2nd Round (2006-2010)	3rd Round (2011-2015)
	4) Research and Innovation Standard including 4 Indicators 5) Academic Service Standard including 2 Indicators 6) Cultural Preservation Standard including 2 Indicators 7) Institutional Management Standard including 5 Indicators 8) Internal QA System Standard including 2 Indicators	3) Academic service Standard including 4 Common Indicators and 3 Specific Indicators 4) Cultural Preservation Standard including 2 Common Indicators and 2 Specific Indicators 5) Institutional Management Standard including 11 Common Indicators 6) Curriculum and Instruction Standard including 9 Common Indicators 7) Internal QA System Standard including 2 Common Indicators The weight of the standards and indicators are varied by the institution groups, and the specific indicators by their emphasis points	4) Cultural Preservation Standard including 2 Basic Indicators (5) Institutional Management and Development Standard including 3 Basic Indicators (6) Internal QA System Standard including 1 Basic Indicators **2** Distinctive Identity Indicators **1** Supportive Indicators
Criteria for certification	Not specified	Specified at both program and institution levels	Specified at institution levels

Table 2.4 (Continued)

	1st Round (2000-2005)	2nd Round (2006-2010)	3rd Round (2011-2015)
Assessment Results	47.69 % of 260 HEIs demonstrated the achievement of ONESQA standards	85.94% of 256 HEIs were accredited 3.91% of 256 HEIs were pending 2.34% of 256 HEIs were not accredited 7.81% of 256 HEIs were undecided	On Process

Source: Office for National Education Standards and Quality Assessment, 2015

Table 2.5 Results of the First External Assessment Round

HEIs Type	Quality Levels				Total
	Poor	Fair	Good	Very Good	
Public University	1	5	16	2	24
Rajabhat Institutes	1	16	23	1	41
Rajamangla Institutes of Technology	8	26	4	0	38
Specific Institutes	2	26	63	2	93
Community College	2	7	1	0	10
Private HEIs	7	35	11	1	54
Total	21	115	118	6	260

Source: Kanjanapanyakom, 2004.

Table 2.6 Results of the Second External Assessment Round

HEIs Type	Quality Levels				Total
	Approved	Probation	Not Approved	No Decision	
Public Universities	14	1	0	13	28
Autonomous Universities	13	0	0	0	13
Rajabhat Universities	38	2	0	0	40
Rajamangla Institutes of Technology	9	0	0	0	9
Specific Institutes	78	1	0	0	79
Community College	15	1	3	1	20
Private Institutes	53	5	3	6	67
Total	220	10	6	20	256

Source: Kanjanapanyakom, 2004.

2.5 Public Funding for Thai Higher Education System

A powerful public funding system for HE is an important component of its well-functioning system to provide the graduates with sufficient skills necessary for their productivity improvement and to supply the right type of research required for boosting technological development, which are two key drivers enhancing competitiveness in an increasingly global market ultimately leading to growth. Public funding for HE is more than just a mechanism to allocate financial resources to HEIs and students (Jongbloed, 2010) as it can be employed as a government's instrument to affect the behavior of HEIs. Woodhall (1992) also suggests that public funding for HE is a mechanism that facilitates dialogue between funders and spending units. As the funder, government is expecting HEIs, the spending unit, to work on achieving particular outcomes.

Moreover, it is often the foundation of other governance instruments to enforce common goals set for higher education and set incentives for certain behavior. In addition, the funding method as well as the size and composition of resources is often adjusted to maximize the desired output with limited resources. Therefore, HE governance and funding systems for HE is two sides of the same coin. Jongbloed (2010) states that the degree of autonomy and monitoring which the government utilizes to direct HEIs so as to meet the societal expectations is an important funding issue when it comes to autonomy in internal resource allocation, but it is a larger governance issue in terms of the balance of responsibilities of HEIs and the government. Funding is, therefore, not an isolated topic but a set of instruments to achieve the goals of higher education.

In case of Thailand, HE system is facing both qualitative and quantitative problems. It is failing to deliver skills significant for enhancing total productivity and research for innovation. A major proportion of HEIs' graduates are not sufficiently competent in their fields of study and while there is a surplus of graduates in the field of social sciences, there is a lack of qualified graduates in the technological and professional fields (OEC, 2003). One explanation of the problems is because public financing goes to institutions regardless of whether they are addressing public goods such as research, externalities, or equity concerns (Di Gropello, 2011).

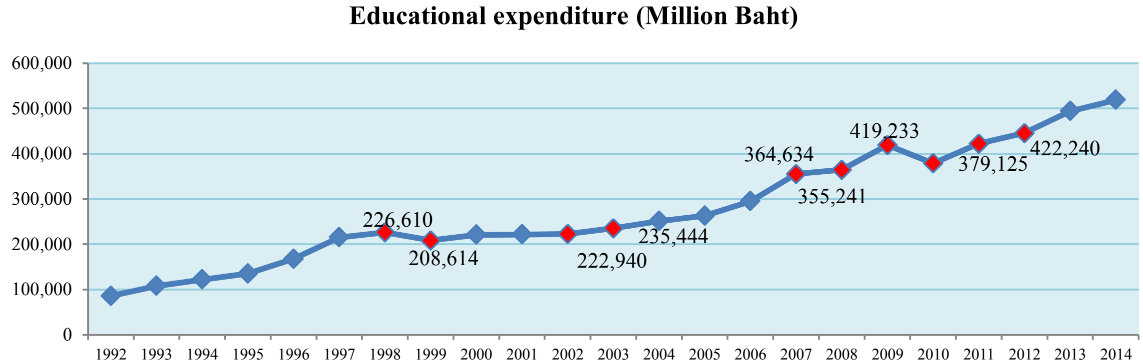
2.5.1 Characteristics of Government Expenditure on Thai Higher Education

In this section some useful information and preliminary figure concerning government expenditure on education during the past 2 decades are reviewed in order to understand the previous trend of educational expenditure. After that, expenditure on HE is also reviewed in order to better understand the pattern and character of the country HE expenditure from past to present.

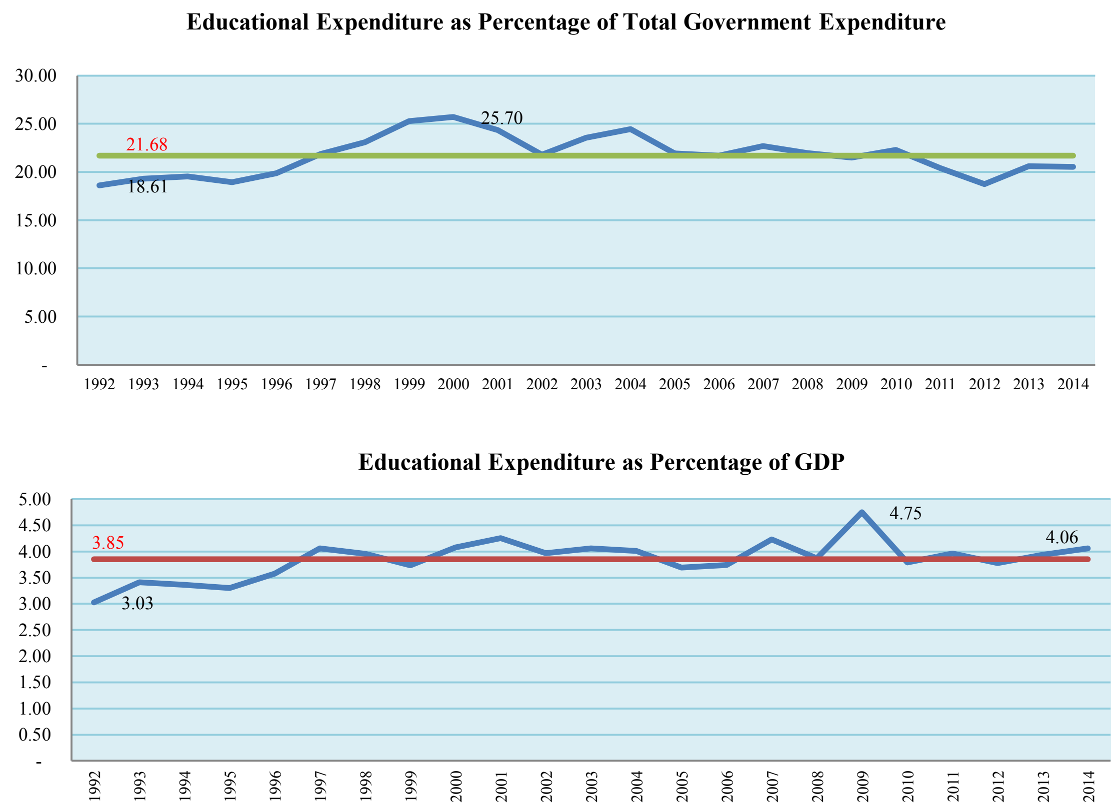
For the past 2 decades, an education sector received the largest share of total government expenditure. The expenditure on this sector was between 85,665 and 518,519 million baht during the period from 1992 to 2014, as shown in Figure 2.10. Over this period, educational expenditure in Thailand had exhibited an upward trend. It began to increase sharply in early 1990 which was in line with the expansion of basic education from 6 to 9 years since the 1992 development plan. After the 1997 financial crisis, the government was forced to shrink overall expenditure resulting in a decrease in educational expenditure from 226,610 million baht in 1998 to 208,614 million baht in 1999, or almost 8 %. The country took over 3 years to return to the pre-crisis educational expenditure levels. During 2003 to 2007, educational expenditure sharply increased again as a result of the implementation of National Education Act of 1999 and the public sector reform around 2000. Sagarik (2013) claims that this apparently increasing in educational expenditure from 235,444 million baht in 2003 to 355,241 million baht in 2007 derives from the institutional shift since 1999. Later, with the policy of free education, educational expenditure obviously sprang up from 364,634 million baht in 2008 to 419,233 million baht in 2009 but in 2010, it was down again to 379,125 million baht as a result of the political tensions and uncertainty. After rebounding to 422,240 million baht in 2011, their expenditure has continuously risen. These pattern changes of government expenditure on education are illustrated in Figure 2.10 (a).

Regarding the share of educational expenditure in total government expenditure, it ranges from 18 to 26 % of total government budget during 1992 to 2014, as shown in Figure 2.7 (b). On average, this share is equal to 21.68 %. Educational expenditure as percentage of total government expenditure rises from below 20 % prior to 1997 to be higher than 20 % after 1997 and reaches the highest point at 25.70 % in 2000. This significant increases in share of educational expenditure from 1995 to 1999 and started to decline after 2000 is similar to the pattern of movement with the absolute amount of educational expenditures which could have derived from the economic development prior to 1997 and the expansion of basic education. After attain the peak point in 2000, the share has revealed a steady and slightly downward trend, as the total government expenditure increase significantly while the educational expenditure itself stays at the same amount.

Concerning the educational expenditure as percentage of GDP, during the last 2 decade, its values ranked from 3 to 5 % or 3.85 % on average over the period from 1992 to 2014 (Figure 2.10 (b)). It continuously grew from early 1990 to the 1997 of financial crisis, but reduced until 2000, and after that it has fluctuated in a narrow band. Although, educational expenditure as percentage of GDP varied in a narrow band, its value demonstrated slightly upward trend. This evidently shows that education is an important sector which public policy makers put highlight on.



(a)



(b)

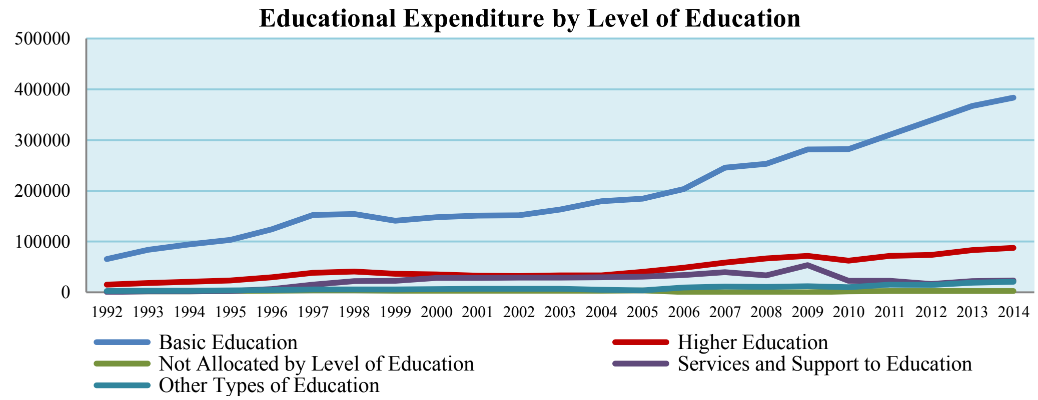
Figure 2.10 Educational Expenditure

Source: Ministry of Education, 2015.

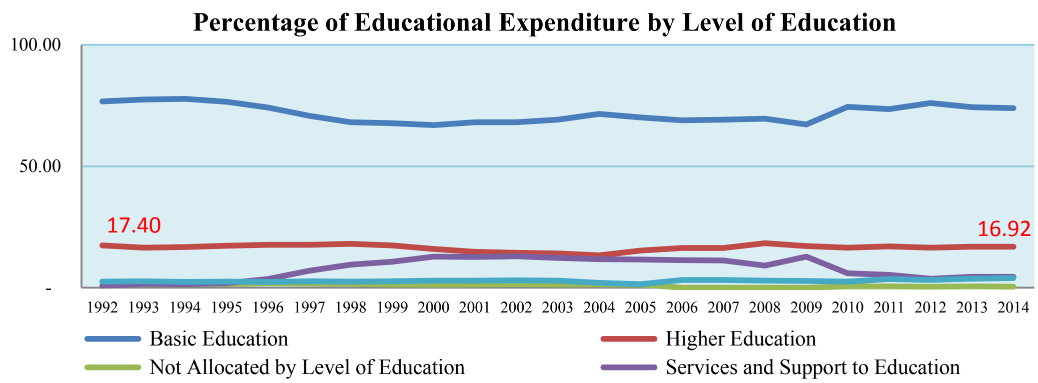
National Economic and Social Development Board, 2015.

In order to get more insightful dimension of education, the trends of educational expenditure by levels of education should be scrutinized. As revealed in Figure 2.11 (a), every level of education demonstrates increasing trend over the time, even though there is a slightly shrinkage in the period between 1998 and 1999. The government educational expenditure is largely allocated to basic education. On average over 1992-2014, the government support for basic education is 71.14 %, 4.35 times higher than HE Figure 2.11 (b). Regarding expenditure on HE, although its values has experienced a slightly but continuous increase since 1992, its share in educational expenditure indicates a significant decrease of allocated budget for HE from 17.40 % in 1992 to 16.92 % in 2014 (Figure 2.8 (b)). This is because the government has to finance 12-years free basic education as a result of the National Education Act of 1999 and expand compulsory education from 9 to 12 years. Inevitably, the priority of government expenditure on education has been given to basic education. Even though the share of expenditure on HE slightly decreases over the past 2 decades, its expenditure per student is still higher than basic education (Figure 2.11 (c)). This implies that enrollment in HE is highly subsidies by the government. Probably, subsidization in this manner is to be regressive because of under-represented of the poor in the HE system. According to Tangkitvanich & Manasnoonphempool (2011), HE subsidization per capita actually grows with household income.

As regards to the distribution of educational expenditure on HE across types of expenditure, the current expenditure, including the one on personnel, operation, investment, subsidy and other, has experienced a steady expansion while the investment expenditure has varied over time, as depicted in Figure 2.12 (a). In addition, over 80 % of government expenditure on HE is allocated to current expenditure while remain allocated to the investment expenditure as shown in Figure 2.12 (b).



(a)



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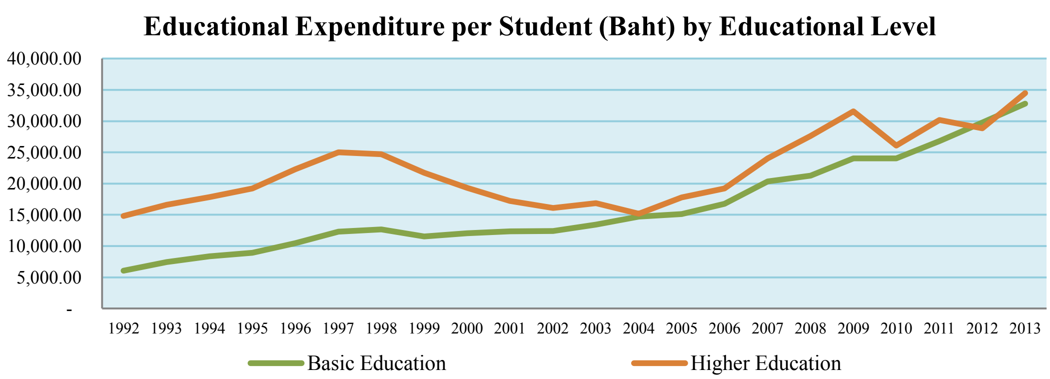
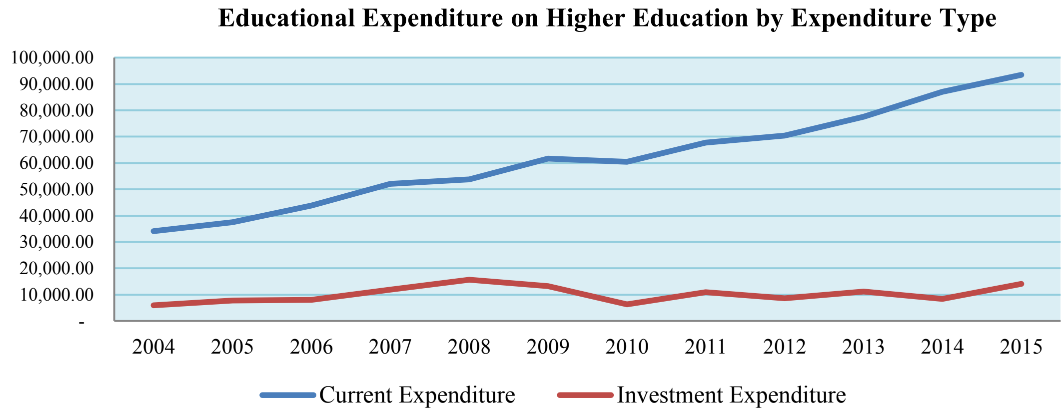


(c)

Figure 2.11 Educational Expenditure by Levels of Education

Source: Ministry of Education, 2015.

National Economic and Social Development Board, 2015.



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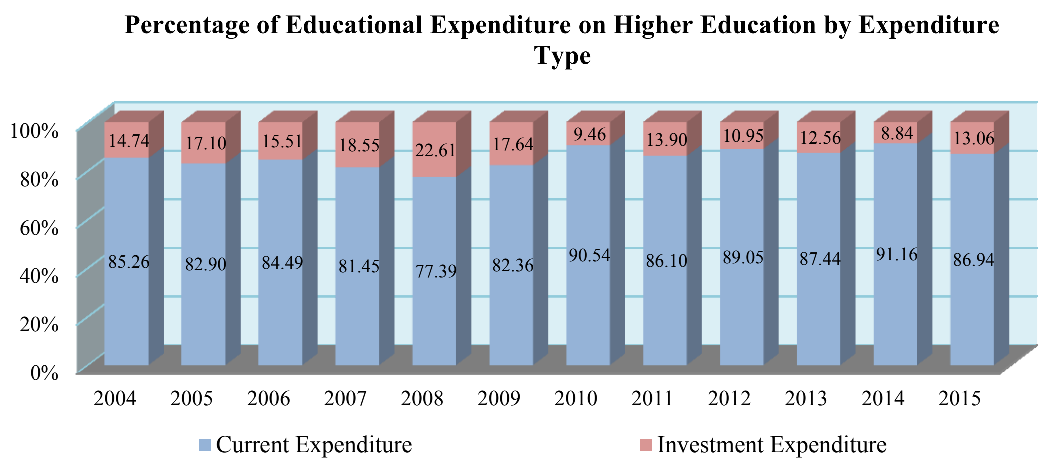


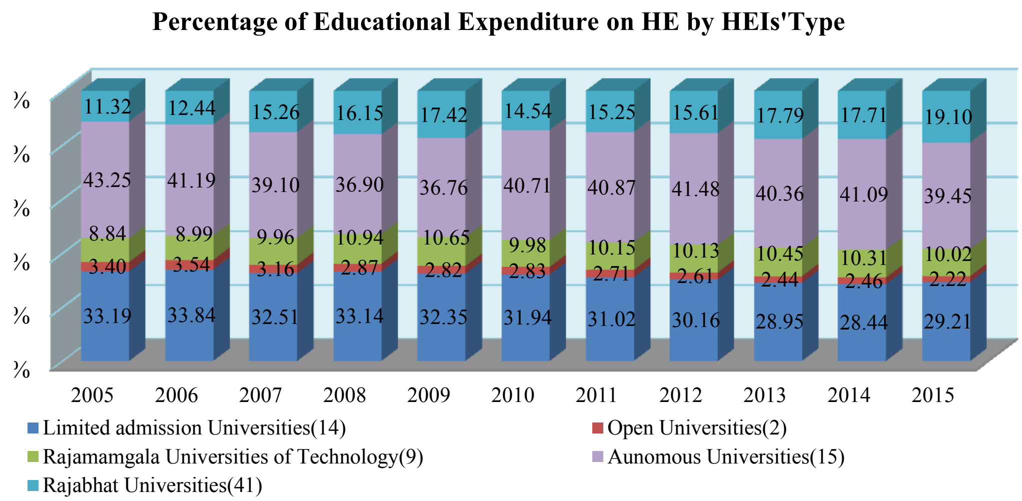
(b)

Figure 2.12 Educational Expenditure on Higher Education by Type of Expenditure

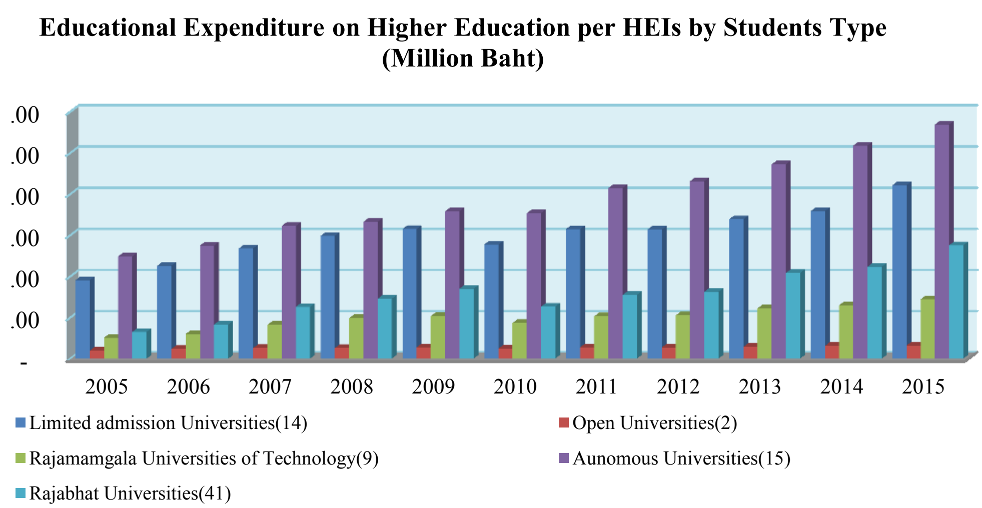
Source: Ministry of Education, 2015**.**

Office of Higher Education Commission, 2015b**.**

As shown in Figure 2.13 (a) and (b), the government budget allocation to public HEIs, in term of percentage and per students, between 1992 and 2014 reflects inequity in the allocation of budget among HEIs' type. Public limited admission and autonomous universities receive more amount of budget than Rajaphat and open universities. 41 Rajabhat and 2 open universities which accommodate students nearly 50 % in HE system receive only 15-20 % of government budget distribution, whereas 15 autonomous universities accommodating only 13.71 % of student enrollment gain the government budget nearly 40 %.



(a)



(b)

Figure 2.13 Educational Expenditure on Higher Education by HEIs Type

Source: Office of Higher Education Commission, 2015b.

2.5.2 Financing for Thai Higher Education

2.5.2.1 Conceptual of Financing for Thai Higher Education

The conceptual of financing for education in all levels, including HE, has already identified in the National Education Act (NEA) of 1999, amendment in 2002, in terms of mobilizing resources and investment for education, source of financing for education, state's responsibility in allocating national budget for education, and system for evaluating utilization allocated educational budget, as follows.

As regards to mobilizing resources and investment for education, the NEA states in chapter 8 (section 58) that there shall be mobilization of resources and investment in terms of budgetary allocations, financial support and properties from the state; local administration organizations; individuals; families; communities; community organizations; private sectors; professional bodies; religious institutions; enterprises; other social institutions; and foreign countries, for use in the provision of education, in order that the state and local administration organizations shall encourage and provide incentive for mobilization of these resources by promoting, providing support and applying tax rebate or tax exemption as appropriate and necessary, in accordance with provisions in the law. According to the education law, there are many channels for mobilizing resources and investment for education revealing in term of organizations such as government, local government, and private sectors and mechanisms such as the nation's budget and education loans funds (OEC, 2009).

In case of allocating national budget for education, section 60 in chapter 8 of the NEA describes that the state shall be responsible for the following:

Allocation of general subsidies for per head expenditure appropriate with the needs of those receiving compulsory and basic education provided by the state and the private sectors, thus grants shall be distributed on an equal basis. Allocation of grants in term of loans is given for those from low-income families, as appropriate and necessary

Allocation of national budget and other special educational resources suitable and in line with the requirements for educational provision for each group of persons with special needs referred to the second, third, and forth paragraphs of section

10, that in this manner, the equality of educational opportunity and justice in accordance with the criteria and procedure stipulated in the ministerial regulations shall be taken into account

Allocation of national budget for operating and capital costs of educational institution in accordance with the policies, the National Education Development Plan, and the missions of the perspective institutions, which shall be allowed freedom in utilization the allocated budget and resources, that in so doing, the quality and equality of educational opportunity shall be considered.

Allocation of national budget as general subsidies for state degree-level institutions is legal entities and state-supervised or public organizations

Allocation of low interest loans to private educational institutions for eventual self-reliance Establishment of the State and Private Education Development Fund.

According to the education law, the government is responsible for provision of national budget for education in terms of supply-side financing such as subsidies for per head expenditure, budget for operating and capital costs, general subsidies and demand-side financing such as student loans funds.

Moreover, the education law has mentioned in section 62 (Chapter 8) that the efficiency and effectiveness in utilization of educational budgetary allocations must be in line with the principles of education, National Education Guidelines and the educational quality and standards required. This indicates that Thai education put emphasize on an evaluation and monitoring system.

Although, the NEA has clearly specified about the financing for HE, it depends on how the relevant government agencies take fully advantage from the principle stated in the law in order to develop the Thai HE system.

2.5.2.2 Structure and Context of Resources Allocation for Higher Education

Structure of resources allocation for Thai HE directly relates to the three laws consisting of: 1) the Budget Procedure Act of 1959, 2) the National Education Act of 1999, amendment in 2002, 3) the Student Loans Fund Act of 1998, and 4) the Royal Decree Establishing the office for National Education Standards and Quality Assessment of 2000. With regards to government agencies involving in resources allocation for HE, OEC (2009) argues that there are 5 major government agencies composing of:1) Bureau of the Budget (BOB), 2) Office of Higher Education Commission (OHEC), 3) Office for National Education Standards and Quality Assessment (ONESQA), 4) Student Loans Fund (SLF), and 5) Office of the Public Sector Development Commission (OPDC). Moreover, there are other research government agencies engaging in allocation of resources for HE in term of research grants such as Thailand Research Fund (TRF), National Research Council of Thailand (NRCT).

The main responsibility of the BOB is to allocate budget for Thai government agencies and state owned enterprises including public HEIs and autonomous HEIs, in line with the Government Policies and the National Economic and Social Development Plan. Moreover, the BOB serves as the center of the budget formulation process and is responsible for coordinating with all government agencies involved in such process, as well as acts as a management consultant to all government agencies. Its main functions in resources allocation for HE is as follows:

1) Distribute of national budget to public HEIs according to 5 objects of expenditure: personnel, operating, investment, subsidies, and other expenditure. However, institutions were permitted to transfer allocated budget between expenditure's objects within the same output

2) Distribute of national budget to autonomous HEIs in a form of block grant. Each institution independently has to decide how to distribute block grant funds within the institution and how to create and control its own budget system

3) Evaluate of HEIs' performance focusing on budget and performance integration by using Performance Assessment Rating Tool (PART). The PART is also employed to assess HEIs' achievement of the linkage between government strategy & policy, budget plan, outcomes, outputs, activities and budget.

OHEC has the mandates involving in allocation of resources for HE as follows:

1) Formulate policy recommendations, HE standards, HE development planning

2) Devise criteria and guidelines for resources allocation as well as providing financial support for establishment of HEIs and community colleges

3) Implement HE monitoring, inspection, and evaluation as instructed by the CHE and compile data and information on higher education.

ONESQA has the responsibilities for developing a system and the criteria for external quality assessment; developing and training external assessors; certifying the external assessors; monitoring and controlling the external quality assessment; and publishing annual reports of the results on the external assessment for the public and the stakeholders.

The main responsibility of SLF, relating to allocation of resources for HE, is to increase higher education opportunity for students of low-income families by providing loans covering tuition fees, education-related expenses and other living expenses.

OPDC is in charge of monitoring and evaluating the performance of public sectors including public and autonomous HEIs to increase their performance and become more efficient and effective. Furthermore, in order to induce public agencies to perform better, OPDC also provided financial incentives for successful organizations during its early days of operation. Given that public and autonomous HEIs receive financial support from the state, they are ultimately subjected to be evaluated by OPDC.

Although, TRF is part of the government system, it lies outside the government administrative bureaucracy. This freedom allows great efficiency on research support in tackling societal problems at both local and national levels. TRF main duty is to assist in the development of researchers and research-based knowledge through making research grants and assisting with research management.

NRCT has responsibility to formulate national research policy and strategy as well as to set the direction in which the national research main plan is driven. The National Research Policy and Strategy covering a five year period has been formulated since 1977 as a research implementation guideline for research agencies along with a framework for analysis of research proposals submitted by government agencies on annual budget allocation.

The relationship between these government agencies in allocation resources for HE can be depicted in Figure 2.14.

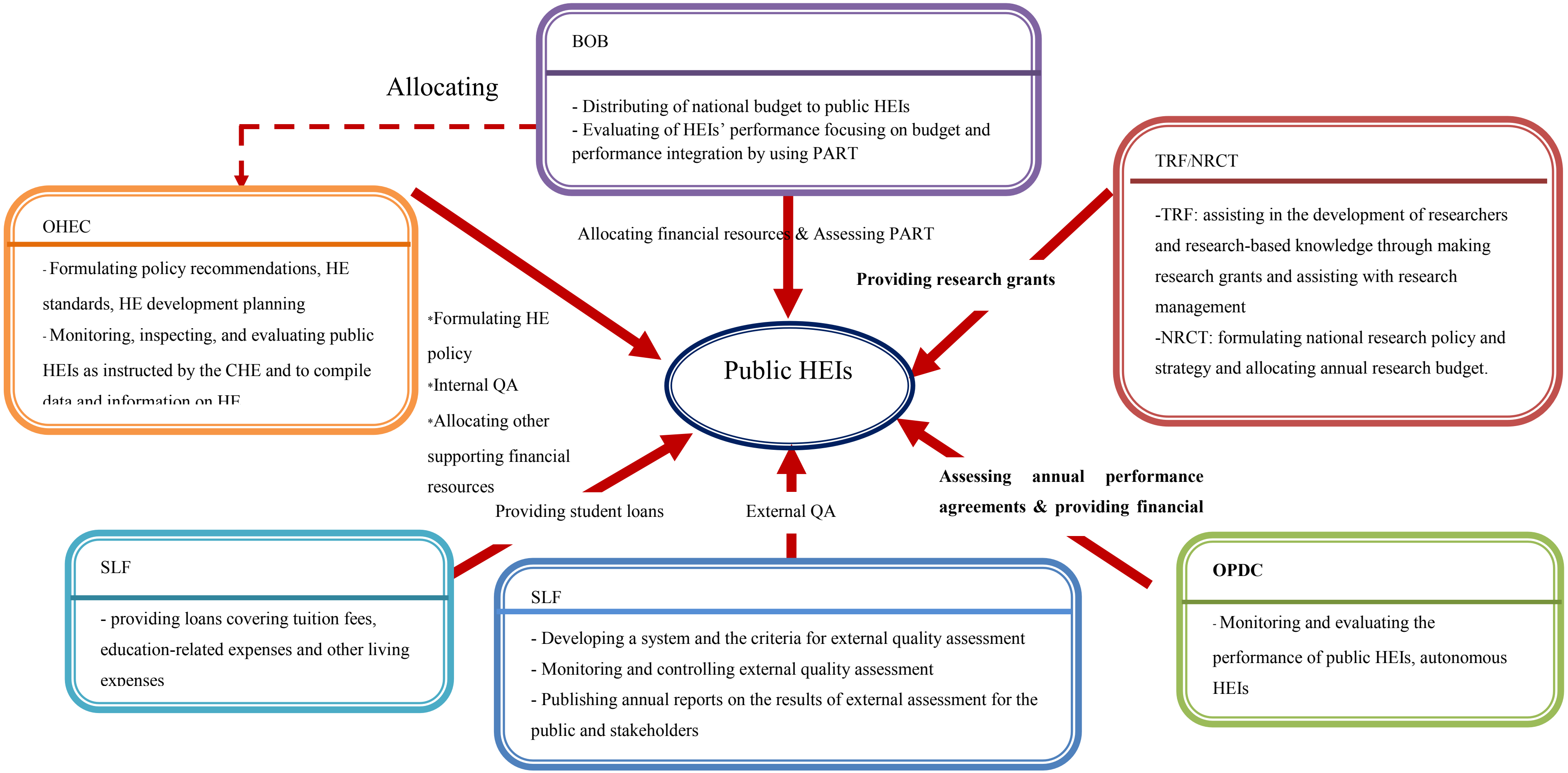


Figure 2.14 Relationship between Government Agencies Involving in Allocation of Resources for Higher Education

Source: Office of Educational Council, 2010.

2.5.2.3 Allocation Mechanisms of Public Financial Resources for Thai Higher Education

In the past decades, Thailand employed several types of allocation mechanisms or budgeting mechanisms to distribute public resource to government agencies. Before the introduction of the current allocation mechanisms, line-item allocation mechanism has been implemented as a national budget scheme since 1982. The line-item allocation mechanism is one type of direct public funding or supply-side funding for government agencies. Since the Thai government was under the bureaucratic system or highly centralization system, the line-item allocation mechanism was employed for all government agencies including public HEIs.

As a government agency, public HEIs were allocated with public resources based on the inputs by line-item allocation mechanism. This mechanism was used as an instrument to control expenditure in which the expenditure should not be surplus or greatly different from an originally-allocated budget. The mechanism of public resources allocation that puts a lot of emphasis on input-based budgeting and puts strictly control of expense instead of emphasizing on the output and outcome of education resulted in an inflexible and inefficient fiscal management and administration (Puntasen et al., 2003). Under the line-item allocation mechanism, HEIs were granted a budget subject to incremental changes on a year-to-year basis. Since the line-item allocation mechanism is highly related to the bargaining power of each institution, accordingly, it does not address the issue of advantage inequality between institutions or ensure adequate funds for institutional development (Saenghong, 2010). Moreover, this allocation mechanism did not support the competition among HEIs, either between public and private HEIs or among public HEIs, in term of seeking additional funding from other sources than the government source (Weesakul, B. et al., 2004). Therefore, the line-item allocation mechanism among other causes was viewed as one main cause contributing to the current crisis of Thai higher education system. In addition, each HEIs had to spend their budget based on rigid bureaucratic rules and any unspent balances on a line-itemed funding had to be returned to the national treasury as they were not permitted to transfer these amounts to reserves under their control. This produced two consequences. First, there was a spending spree at the end of every year as institutions discharge accumulated funds. Second, there was no build-up of a reserved fund.

Additionally, as a mainly supply-side financing system, the allocation mechanism channeled most of public resources through producers of education services, i.e. HEIs. Under this system, the change in students' need could not be flexibly responded because changes in public resources for HEIs were mainly due to new study program or research units, but not students' need (Tangkitvanich & Manasboonphempool, 2011). Moreover, since the income received from tuition fees collected by public HEIs was too low, accounted for 10-20 % of the HEIs budget (Kirtikara, 2002), and did not reflect the true cost of production (KMITT, 2005), the budget was insufficient to achieve the goal of academic excellence. It also caused private HEIs to face with limited opportunities in mobilizing resources from other sources resulting from their ability to compete with the public HEIs on an equal footing. As a result of mainly supported by public resources, accounted for 20-80 % of the HEIs budget (Kirtikara, 2002), most public HEIs had no incentive to mobilize other resources from all parts of the society. Consequently, educational resources were not sufficient to develop institutions to become academically excellent.

As above mentioned, the old public resources allocation mechanism for HE led to many problems in Thai HE system, thus, there had been an urgent need to reform the Thai funding system for HE. In 2005, performance-based allocation mechanism was partially implemented as the new funding mechanism and particularly applied to autonomous HEIs. This allocation mechanism originated from combining the input-based funding mechanisms and output-based funding mechanisms. The performance-based allocation mechanism is the funding mechanism based on student body and graduate output in various fields of specialization such as degrees awarded, degrees awarded in particular fields, average time of degree completion, and performance of graduates on post graduate education. In addition, the reports of results on performance indicators are considered as factor to determine the total funding for a public higher education institution (Saenghong, 2010).

Under this allocation mechanism, HEIs was directly allocated government funds in a form of block grants or in a large sum. The, unlike categorical grants, block grant is a large sum of the government funds allocated directly to HEIs with a broad provision. The amount of block grants allocated to each institution can be varied on availability of government budget in each fiscal year. The authority and responsibility in financial management is given to institutions along with block grants. Each institution independently has to decide how to distribute block grant funds within its institution and how to create and control its own budget system. The government neither guide nor control the institutional expenditure but plays role of promoter, supervisor, and policy maker. Besides, the block grants allocated by the government are needed to be combined with income generated by a university itself to make-up an annual university income. In other words, the annual income of university is derived from two major sources: a block grant from the government and income from institutional-self generation. The institution also has only one budget accounting system instead of two separate budget accounting systems which are government budget system and university budget system as in the past funding framework. However, how to calculate the unit cost that is accurate and appropriate becomes an important issue that the government and universities have to cooperatively work out. The unit cost needs to be acceptable and agreeable to both funding provider (the government) and funding receiver (universities) but is still in the process of estimation.

Even though the performance-based allocation mechanism has been established since 2005, up to now the legislation concerning funding of higher education has not been authorized. The funding of HE in Thailand is not yet based on criteria related to performance. While performance-based funding has been implemented to some extent, other elements of government funding frameworks such as resource mobilization, institutional external income generation, the shift from supply-side funding to demand-side funding are still in the discussion and decision making process.

As regards to resource mobilization, even though the educational law encourages other sources and public to financially support higher education, the other source such as private organizations and corporatization, local administration organizations, communities, religious institutions, and social organizations do not increase their roles in contributions for HE. The government still remains the major source of HE financial support for higher education. Resource mobilization for education has not progressed as much as expected and there is no effective scheme for inducing people who benefit from university education or operations to contribute to its performance and functions.

Concerning external income generation, as stated in the National Education Act of 1999 (section 58 and 60), the sources of HEIs income are from diversity. The revenue of academic institutions can derive not only from the government source in various forms such research grants and subsidy, but also from nongovernment sources such as donations, gifts, private organizations, and beneficiaries of university output (graduate, research and service). In contrast, HEIs income under the bureaucratic system largely come from the government budget, along with small portion of supplementary income from tuition fees. Briefly, HEIs under the new funding framework can diversify sources of income to increase financial resources, provide discretionary money, and reduce governmental dependency if they are well supervised and committed to income generating activities.

Apart from moving toward performance-based funding or measurable output indicators, resource mobilization, and external income generation, increasing funding on demand-side is another main element of a new funding framework. This element is regarded as one important effort of the government to shift supply-side funding to demand-side financing. This means that funding for instructional costs used to be provided to institutions is now transferred and allocated directly to students through forms of governmental financial assistance schemes, called Income Contingency Loans (ICL), and need-based grants.

In case of Thailand, the analysis from relevant documents reveals that there are four main rationales for the government and policymakers to advocate shifting funding from supply side (institutions) to demand side (students) or support the notion of cost sharing between the government and students and parents (Saenghong, 2010).

The first reason is the notion of equity: the view that those who benefit should at least share in the costs. It is believed that further study in HE brings the greatest private return to the students (or parents), either in future earning capacity, in prestige, job security, or anything else of value in a profession or vocation. As a result, students of HE should contribute to the instructional costs or tuition fee of higher education. At present, the government supports for students in HE accounts for 70- 80 % of the total education cost while the students take responsibly for only 10-20 % of their financial burden.

The second reason is to address the issue of unequal government funding to students of public HEIs over students at private ones as well as a disproportionate number of the HE beneficiaries. Although, public institutions funded by the government are supposed principally to serve students particularly those from low income families, it turns out that a large number of the HE beneficiaries of public institutions are from middle, upper middle, and upper income families who are able to pay a portion of the cost of instruction.

The third reason is the government‘s attempt to improve education quality of higher education through the pressure from students and parents who become consumers or purchasers. Within this idea, the quality of higher education will be based on efficiency since the payment of some tuition fees will make students and families more discerning consumers and the universities more cost-conscious providers. The institutions are also pressured to be more competitive in improvement and enhancement of educational quality, thus, becoming excellent in academics.

The fourth reason is to balance the introduction of tuition increases based on cost recovery. As presented, tuition fees based on price regulation which has been used by the Thai HE for several decades have been replaced with the ones that fees based on cost recovery. The tuition is likely depended on market mechanisms and it can be raised if it is needed and is appropriate and acceptable.

CHAPTER 3

LITERATURE REVIEW

Constructing a framework to investigate the influences of public funding for HE on HEIs' performance, the relevance concepts, theories, and previous studies are reviewed as follows: 3.1 concept of institutional performance in HE, 3.2 definitions and measurement of technical efficiency, 3.3 methods for measuring technical efficiency, 3.4 Data Envelopment Analysis (DEA), 3.5 scale efficiency, 3.6 identification on the nature of return to scale, 3.7 previous studies on HEIs' technical efficiency measurement using DEA, 3.8 previous studies on the influences of public funding on HEIs' performance.

3.1 Concept of Institutional Performance in Higher Education

Public HEIs heavily depend on scarce government resources. Accordingly, they must increasingly compete for the resource, not only with sectors, but also with other institutions within HE sector. Moreover, as a recipient of government funding, public HEIs performance need to be monitored and evaluated whether the government's objective are being satisfied.

As a government and non-for-profit organization, public HEIs have characteristics that differentiate them from other private organizations such as lack of profit motive, diversity and uncertainty of HEIs' goals, diffuse of decision making, and poorly understood production technology (Lindsay, 1982). These characteristics prohibit them from using the principles of profit maximization and cost minimization as a mean for measuring institutional performance. The arguments are confirmed by Johnes (2006a, 2008) that the measuring of HEIs' efficiency is problematic because of HE characteristics that make it difficult to measure efficiency such as non-profit-making, an absence of output and input prices, and multiple inputs-outputs production process. Therefore, in public HEIs context, the measurement of institutional performance is difficult to accomplish. Although, the measurement of public HEIs' performance is an intricate task due to the reasons as aforementioned, it is inevitability for the purpose of monitoring, evaluating, and improving institutional performance.

In order to evaluate the institutional performance in HE context, the concept of institutional performance should be firstly clarified, as detailed in Figure 3.1. Following Worthington and Dollery (2000), overall performance of public HEIs, as a government and non-for-profit organization, can be divided into two components: efficiency and effectiveness. Efficiency describes how well an organization uses resources in producing services, that is, the relationship between the inputs and the outputs, while, Effectiveness refers to the degree to which a system achieves its program and policy objectives, that is, the relationship between the inputs and the outcomes in terms of appropriateness (matching service to client needs); accessibility (aspects such as affordability, representation amongst priority groups and physical accessibility); and quality (the process of meeting required standards or incidences of service failures). Moreover, the effectiveness, which illustrates the success of resources using to achieve the objectives pursued, is harder to achieve than efficiency because it is influenced by other external factors beyond HEIs control. Therefore, in this study, the performance of HEIs is principally focused on efficiency dimension.

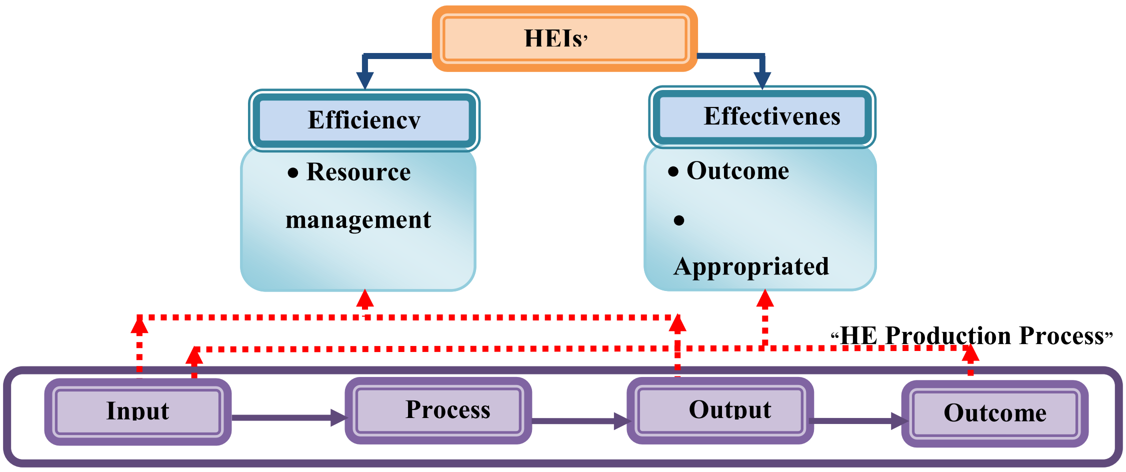


Figure 3.1 The Concept of Institutional Performance in Higher Education
Source: Worthington and Dollery, 2000.

3.2 Definition and Measurement of Technical Efficiency

The modern literature on the measurement of efficiency begins with the paper by Farrell (1957) which was greatly influenced by Koopmans (1951)'s formal definition and Debreu (1951)'s measure of technical efficiency.

Farrell (1957) extended the work initiated by Koopmans and Debreu by introducing the idea of overall efficiency (or total economic efficiency) which consists of two components: technical efficiency and allocative efficiency. The first component reflects the ability of a firm to avoid waste by producing as much output as technology and input usage allowed or by using as little input as required by technology and output production. In other words, the firm is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, or, if a reduction in any input requires an increase in at least one other input or a reduction in at least one output (Koopmans, 1951). The second component refers to the ability of a firm to combine inputs and/or outputs in optimal proportions in light of prevailing prices. Thus, if a firm uses its resources completely allocatively and technically efficiently, then it can be said to have achieved overall efficiency. Alternatively, to the extent that either allocative or technical inefficiency is present, then the firm will be operating at less than overall economic efficiency.

In Farrell's seminal work, technical efficiency is measured by the method which is similar to Debreu's measure of technical efficiency- a radial measure. This measure is known as Debreu-Farrell's measure of technical efficiency. The radial measure of technical efficiency is defined as one minus the maximum equiproportionate reduction in all inputs that is feasible with given technology and outputs, or one minus the maximum equiproportionate expansion in all outputs that is feasible with given technology and inputs. In both cases, a value of unity indicates technical efficiency because no radial adjustment is feasible, and a value different from unity indicates the severity of technical inefficiency. In other words, the measurement of technical efficiency involves a comparison of actual performance with optimal located on the relevant production frontier.

To clearly understand the concept of technical efficiency measurement, it is necessary to relate the Debreu-Farrell's measure of technical efficiency to the structure of production technology (see details in Daraio & Simar, 2007). In doing that, some notations and terminologies should be reviewed as follows. Given a list of n inputs and m outputs, in economic analysis, the technology of any productive unit can be defined by means of a set of points, S, the production set. This set is defined as follows in the Euclidean space R_{+}^{n+m} as:

$$\mathbf{S} = \{(\mathbf{x}, \mathbf{y}) | \mathbf{x} \in \mathbf{R}_{+}^{\mathbf{n}}, \mathbf{y} \in \mathbf{R}_{+}^{\mathbf{m}}, (\mathbf{x}, \mathbf{y}) \textbf{ is feasible}\},$$

Where x is the input vector, y is the output vector and "feasibility" of the vector (x, y) means that, within the unit under consideration, it is physically possible to obtain the output quantities $y_1, \dots, y_m$ when the input quantities $x_1, \dots, x_n$ are being used (all quantities being measured per unit of time). However, it is useful to define the production set, S, in terms of its sections, defined as the images of a relation between the input and the output vectors that are the elements of S.

The input requirement set (for all y ∈ S) can be defined as:

$$\mathbf{L}(\mathbf{y}) = \{\mathbf{x} \in \mathbf{R}_{+}^{\mathbf{n}} | (\mathbf{x}, \mathbf{y}) \in \mathbf{S}\}.$$

An input requirement set L(y) consists of all input vectors that can produce the output vector $y \in R_{+}^{m}$.

The output correspondence set (for all x ∈ S) can be defined as:

$$\mathbf{P}(\mathbf{x}) = \{\mathbf{y} \in \mathbf{R}_{+}^{\mathbf{m}} | (\mathbf{x}, \mathbf{y}) \in \mathbf{S}\}.$$

P(x) consists of all output vectors that can be produced by a given input vector $x \in R_{+}^{n}$.

The isoquants or efficient boundaries of the sections of S (L(y), P(x)) can be defined in radial terms as follows.

In input space, the input isoquant is defined as:

$$\partial\mathbf{L}(\mathbf{y}) = \{\mathbf{x} | \ \mathbf{x} \in \mathbf{L}(\mathbf{y}), \alpha\mathbf{x} \notin \mathbf{L}(\mathbf{y}); \ \forall\alpha, \ \mathbf{o} < \alpha < 1\},$$

and in output space, the output isoquant is defined as:

$$\boldsymbol{\partial}\mathbf{P}(\mathbf{x}) = \{\mathbf{y}|\ \mathbf{y} \in \mathbf{P}(\mathbf{x}), \lambda\mathbf{y} \notin \mathbf{P}(\mathbf{x});\ \forall\lambda,\ \lambda > 1\}.$$

Turning back to the Debreu-Farrell's measure of technical efficiency, it is possible to characterize any points (x, y) in S as:

1) Input efficient if $x \in \partial L(y)$
2) Input inefficient if $x \notin \partial L(y)$
3) Output efficient if $y \in \partial P(x)$
4) Output inefficient if $y \notin \partial P(x)$.

From what stated above, firms are technically efficient according to Debreu-Farrell' measure of technical efficiency, e.g. in an input-oriented approach, if they are on the boundary of the input requirement set, or, in an output-oriented approach, if they are on the boundary of the output correspondence set. In other word, Debreu-Farrell's measure of technical efficiency terms on firms on the isoquant (either input isoquant or output isoquant) as efficient firms. Then, the Debreu-Farrell efficient subsets of L(y) and P(x) in input space and output space, respectively, can be expressed as:

1) Debreu-Farrell efficiency subset of L(y): $\mathbf{Eff.^{DF}\,L(y) = \boldsymbol{\partial}L(y)}$
2) Debreu-Farrell efficiency subset of P(x): $\mathbf{Eff.^{DF}\,P(x) = \boldsymbol{\partial}P(x)}$.

Once the efficient subsets have been defined (either in input or output space), the efficiency measure of a firm operating at the level (x, y) can be determined by considering the distance from this point to the frontier.

Obviously, the efficient frontier could be considered in two directions regarding the defining of production set. Therefore, the Debreu-Farrell's input-oriented measure of technical efficiency ($\mathrm{TE^I}(x, y)$) can now be given a somewhat formal interpretation as a value of the following function. $\mathrm{TE^I}(x, y) = \mathbf{min}\{\theta|\ \theta\mathbf{x} \in \mathbf{L}(\mathbf{y})\}$.

All $\mathbf{x} \in \mathbf{L}(\mathbf{y})$, $\mathrm{TE^I}(x, y) = \theta^* \leq 1$ and for $\mathbf{x} \in \boldsymbol{\partial}\mathbf{L}(\mathbf{y})$, $\mathrm{TE^I}(x, y) = 1$. $\mathrm{TE^I}(x, y) \leq 1$, implies that the radial contraction of inputs that the firm should achieve and be considered as being input-efficiency in the sense that $(\theta^* x, y)$ is on the input isoquant, $\mathbf{\partial L(y)}$. The Debreu-Farrell's input-oriented measure of technical efficiency can be depicted in Figure 3.2

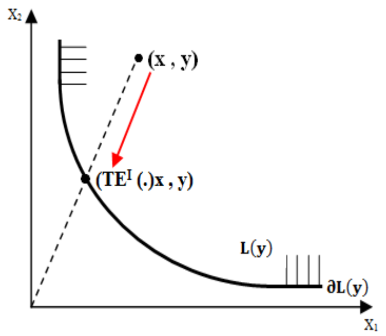


Figure 3.2 Input-Oriented Measure of Technical Efficiency

Alternatively, the Debreu-Farrell's output-oriented measure of technical efficiency ($TE^O(x, y)$) is a value of the following function: $TE^O(x, y) = \mathbf{max}\{\emptyset | \ \emptyset\mathbf{y} \ \in \mathbf{P(x)}\}$. For all $\mathbf{y} \in \mathbf{P(x)}$, $TE^o(x, y) \ \geq 1$ and for $\mathbf{y} \in \mathbf{\partial P(x)}$, $TE^O(x, y) = 1$. In the same way with input-oriented measure, $TE^O(x, y) \geq 1$ implies the proportionate increase of outputs that the firm should achieve and be considered as being output-efficiency in the sense that (x, $y/TE^O(.)$) is on the output isoquant, $\mathbf{\partial P(x)}$. The Debreu-Farrell's output-oriented measure of technical efficiency can be depicted in Figure 3.3

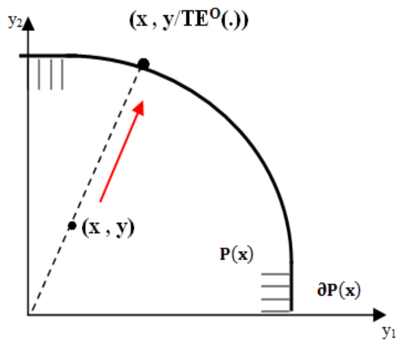


Figure 3.3 Output-Oriented Measure of Technical Efficiency

3.3 Methods for Measuring Technical Efficiency

As mentioned in section 3.2 the measurement of technical efficiency involves a comparison of actual performance with optimal performance located on the relevant production frontier. This implies that the production frontier of the fully efficient firm must be known. As this is usually not the case, the estimation of empirical production frontier by using observed data is required in order to estimate the efficient production frontier.

Generally, there are three kinds of criteria used to classify the method of efficiency frontier estimation: 1) statistical or non-statistical, 2) parametric or non-parametric, and 3) stochastic or non-stochastic. Johnes (2004) summarized the distinction among these criteria, as followed.

Statistical or non-statistical approach: the statistical approach assumes that the efficiencies (the differences between the production unit's observed output and the output which could be achieved if it were producing on the production frontier) follow a specific distribution. On the other hand, non-statistical approach makes no assumptions regarding the distribution of inefficiencies

Parametric or non-Parametric approach: under the parametric approach, a particular functional form for the production function is also assumed, for example the Cobb–Douglas, while under non-parametric approach there is no assumption about the functional form for the production function, but it does impose some technical restrictions such as monotonicity and convexity. In order to construct a convex hull representing the efficient frontier, linear programming technique is applied with the observed input and output data.

Stochastic or non-stochastic approach: The stochastic approach is based on the principle that deviations from the production function are a consequence, not just of inefficiency but also of measurement errors, random shocks and statistical noise. Therefore, in the stochastic models, the residual composes of two components: inefficiency and random, and in practice, each of the two components requires a specific distribution. In contrast, deterministic methods assume that any deviations in observed output from the production frontier are solely a consequence of inefficiency.

It is valuable to note that the statistical approach is often (but not always) parametric. Therefore, the statistical, parametric approaches use a simple mathematical form to represent production technology, hence, provide estimates parameters of the frontier, the significance of which can be tested using standard. However any misspecification errors (either of the production function or of the inefficiency distribution) are incorporated in the efficiency measure (Fried, Schmidt, & Lovell, 1993). Furthermore, the statistical, parametric approach is not easily applied in a situation where there are multiple inputs and multiple outputs.

Additionally, the non-statistical is often (but not always) non-parametric. Thus, the non-statistical, non-parametric approaches avoid problems of misspecification (of both the production function and the distribution of efficiencies) since no distributions are specified. Furthermore, programming methods can easily be used in a production situation where there are both multiple inputs and multiple outputs. A disadvantage of the non-statistical, non-parametric approach is that it provides no estimates or significance tests of parameters and that the convex hull is defined by using information of only a small number of observations in the sample.

Of the eight possible permutations of these criteria (as shown in Figure 3.4), the most common methods fall into one of these two categories: stochastic, parametric, and statistical method known as Stochastic Frontier Analysis: SFA; and non-stochastic, non-parametric, and non-statistical method, known as Data envelopment Analysis: DEA.

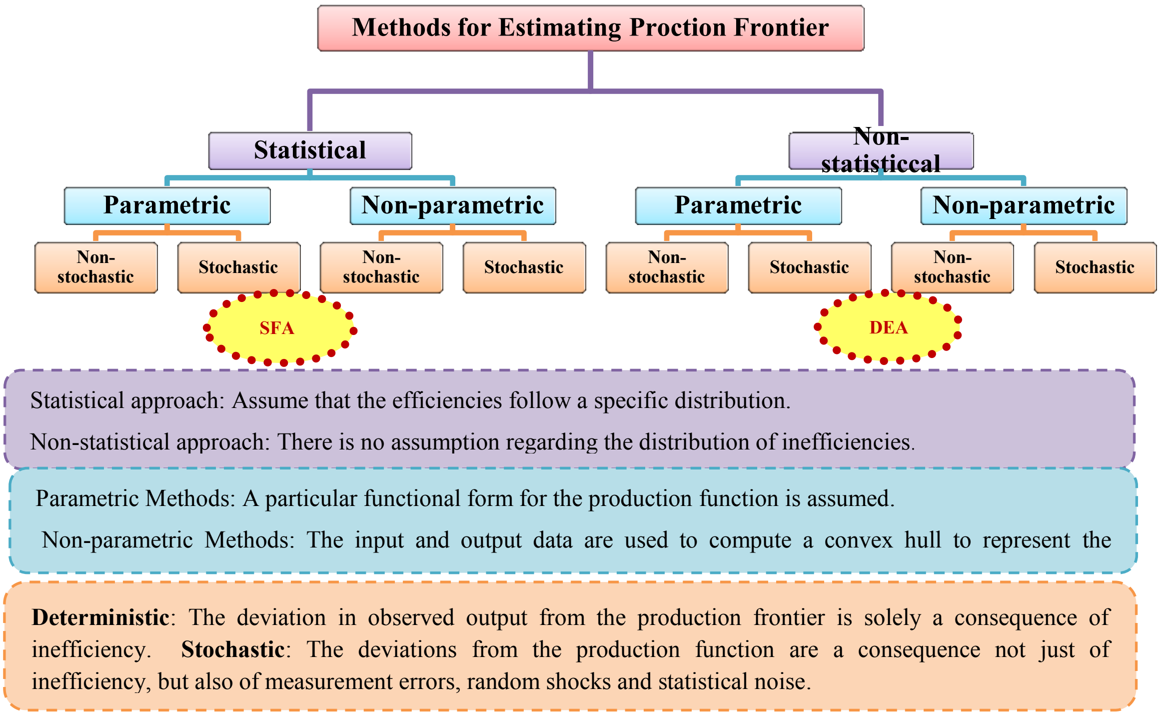


Figure 3.4 The Method for Estimating Efficient frontier

Source: Johnes, 2004.

Although both SFA and DEA are applied to identify efficient production frontier and to evaluate the efficiency, they are fundamentally different in their construction and underlying assumptions as detailed in Table 3.1.

In SFA approach, a functional from of production frontier is pre-defined. The coefficients estimated by the SFA approach are assumed to be constant across observations. Moreover, deviations (as measured by the error term) away from the determined production frontier is composed of two parts. The first is an asymmetric half-normal distribution component representing inefficiency. The second is a normal distribution component capturing statistical noise beyond the control of production unit, including both uncontrollable factors directly concerned with the 'actual' production function (such as differences in operating environments) and random errors (such as misspecification of the production function and measurement error). Latter component is analogous to the residuals that are yielded by other statistical regression type analysis whereas its presence allows the tools of statistical inference to be employed.

In contrast to SFA method, DEA requires no pre-established functional form of production frontier, but the production frontier is calculated from the sample of observation. It uses linear programming methods to assign an observation-specific set of weight to outputs and inputs in such a way that the ratio of weighted output to weighted input is maximized for each observation. This ratio can be used to construct the efficient frontier. Moreover, as a deterministic approach, the DEA requires no types of inefficiency (residual) distribution, whereas all deviations from the efficient frontier are due to inefficiency only, which means that there is no space for any types of bias resulting from environmental heterogeneity, external shocks, measurement error and omitted variables (Worthington, 2001). In addition, under this approach, it is impossible in which probability statements of the shape and placement of the production frontier can be made.

Table 3.1 The Comparison of DEA and SFA Technique

	Data Envelopment Analysis (DEA)	Stochastic Frontier Analysis (SFA)
Characteristics	1) There is no functional from of efficient frontier which is pre-defined. The efficient frontier is constructed from a sample observation by using linear progrmming techniques. 2) The specific type of inefficiency (residual) distribution is not required. 3) All deviations from the efficient frontier are due to inefficiency. 4) Each observation is attatched to its own set of coefficient. 5) the efficiency of a given firm is calculated relative to the performance of other firms producing the same goods or services rather than against an idealised standard of performance.	1) A functional from of efficient frontier is pre-defined. 2) The set of residuals that attach to the observations requires a distribution type of error term. 3) The residuals compose of 2 components: (1) Non-normal distribution component representing the inefficiency; (2) Normal distribution component capturing a statistical noise beyond the control. 4) The coefficients estimated by the method are assumed to be constant across observations. 5) The absolute efficiency of each firm is determined against some imposed technology or estimated efficient frontier.
Advantages	1) Efficiency estimated in DEA are based on the behavior of other firms; as a result there is no need to draw assumptions about efficiency a priori. The efficiency identification is directly observable since other firms have already demonstrated higher levels of efficiency (can be achieved). 2)The danger of imposing incorrect assumptions on the model is alleviated because of the non-parametric nature of DEA that requires only few assumptions on the underlying technology.	1) As explicitly allowance for the presence of noisy data, SFA can effectively deal with random errors through statistical inference on the estimated parameters. 2) In term of relative versus absolute efficiency, since SFA characterizes the behavior of an average firm, estimates are much less sensitive to changes in a single data point.

Table 3.1 (Continued)

	Data Envelopment Analysis (DEA)	Stochastic Frontier Analysis (SFA)
	3) DEA could handle with efficiency measurement of multiple inputs and multiple outputs. 4) DEA has an ability to identify source and amounts of inefficiency in each input and each output for each firm. (5) DEA provides a set of benchmark firms that inefficient firms should imitate in order to be more efficient.	
Disadvantage	1) Since it makes no allowance for the possibility of random errors in the data, it isn't capable to statistical inference. 2) Because of non-stochastic characteristic of DEA, the existence of omitted variables, errors of measurement of the inputs and outputs and any other statistical noise will contaminate the efficiency scores 3) DEA constructs a frontier from the data itself, then, the efficiency score derived in any given analysis are only valid in particular sample. 4) DEA efficiency scores are sensitive to input and output specification and the size of sample size	1) The incorrect assumptions on functional form, distributional of statistical noise and inefficiency can lead to the possibility of biased and/or inconsistent efficiency estimates. 2) The dependent variable in regressions function can only be a single value, then it is not possible to mutually estimate the influence of explanatory variables have on multiple dependent variables.

Source: Worhtington, 2001.
Salerno, 2003.
Johnes, 2004.

Nevertheless, both DEA and SFA possesses its own strengths and limitations, neither is generally regarded to be superior to the other. Moreover, there is no agreement in the previous studies regarding the preferred method of analysis. As a result, the choice of the method depend on the specific situation where some estimations prove to be more superior.

In the context of public HE, the measurement of HEIs' technical efficiency is difficult than any organizations in private sector. The reason is that public HEIs possess some characteristics as follows: 1) operation in public HEIs are typically complex with a variety of inputs and outputs taking part in the production process, and with a diverse objective; 2) knowledge of input and output prices in public HEIs production process is often unknown; 3) some outputs of public HEIs can't be measured because of their nature such as HEIs social externalities; and 4) imposing a functional form on the production process is not an easy task in HE context. Together with the features and advantages of DEA Methods, this study adopts DEA method for measuring technical efficiency of public HEIs

3.4 Data Envelopment Analysis (DEA)

DEA, firstly introduced by Charnes, Cooper, and Rhodes (1978), can be defined as a non-stochastic, non-statistical, and non-parametric method to measure relative efficiency of homogeneous units called Decision Making Units (DMUs) by comparing it with a group of DMUs that transforms the same group of measurable inputs into the same types of measurable outputs. Although, the theoretical foundations in Charnes et al. (1978)'s work based on Farrell (1957), they extended to address the problem of efficiency measurement for DMUs with multiple inputs and multiple outputs by creating a single 'virtual' output and 'virtual' input for replacement (Cooper, Seiford, & Tone, 2007).

The term DMUs is rather loose in allowing flexibility to its use over a wide range of possible applications. According to Cooper et al. (2007), a DMU is generally regarded as the entity that is to be evaluated in terms of its abilities to convert inputs into outputs. These evaluations involve governmental agencies and not-for-profit organizations as well as business firms. Recent years have seen a great variety of

DEA applications for use in evaluating the performances of different kinds of entities engaged in many activities with various contexts in many countries. These DEA applications have used DMUs of various forms to evaluate the performance of entities, such as hospitals, US Air Force wings, universities, cities, courts, business firms, and others, including the performance of countries, regions, etc. Additionally, most of these DMUs are non-profit organizations where the measurement of performance efficiency is difficult (Ramanathan, 2003). Generally, the efficiency of commercial organizations can be assessed easily by their yearly profits or their stock market indices. In contrast, such measures are not applicable to non-profit organizations. Moreover, the fact that DMUs consume a variety of identical inputs and produce a variety of identical outputs amplifies the problem complication.

Since its introduction in 1978, DEA has remarkably developed in both empirical application and theoretical development. According to the study of Liu, Lu, Lu, and Lin (2013) surveying 4,936 papers listed in the ISI Web of Science (WOS) database from 1978 through August 2010, the survey results show that around two-thirds (63.6%) of DEA papers embed empirical data while the remaining one-third are purely-methodological. The purely-methodological articles dominated the first 20 years of DEA development, but the accumulated number of application-embedded papers caught up to purely-methodological paper in 1999. Moreover, among the multifaceted applications, the top-five sectors addressed are: banking, health care, agriculture and farm, transportation, and education.

The DEA application on education attracts the highest attention in the early days of DEA development. There appears to be two literature streams of DEA application on education. The studies on the efficiency of HE including the one of Bessent, Bessent, Charnes, Cooper, and Thorogood (1983), Sinuany-Stern, Mehrez, and Barboy (1994), Arcelus and Coleman (1997). The other streams examining that of basic education include Ray (1991), Kirjavainen and Loikkanen (1998), Mancebon and Molinero (2000), and Bradley, Johnes, and Millington (2001). However, recent trend of efficiency studies in the education category clearly focuses on the HE sector.

The objective of DEA is to construct a non-parametric piece-wise frontier (or efficient frontier) which envelopes all sample observations, by using linear programming techniques. This frontier is determined by units being on it, that is efficient DMUs. On the other hand, units not being on that frontier can be considered as inefficient DMUs and their technical efficiency score is calculated for each one of them, relative to the frontier. The best practice units, then, can be extracted from the group of DMUs by comparing their inputs and outputs to other DMUs under consideration.

Regarding the DEA objectives, the procedure of DEA can be divided into 3 following steps. In the first step, a non-parametric piecewise surface (or envelopment frontier) which provides a benchmark technology for all DMUs in a sample is constructed by using linear programming technique and the surface is determined by those units that lie on it, that is the efficient DMUs. In the second step, hypothetical units are generated on the frontier to serve as reference units for inefficient DMUs and these reference units are constructed as linear combinations of the most efficient units on the frontier. In the third step, efficiency measures are then calculated relative to the reference units on the surface. A unit on the efficient frontier is given a score of 1. Units that do not lie on that surface can be considered as inefficient and an individual inefficiency score is calculated for each one of them, given a score between 0 and 1.

Even though DEA has no assumptions regarding the distribution of inefficiencies or the functional form of the production function, it does impose some following general assumptions about the production technology (Ray, 2004). These assumptions are fairly weak and hold for all technologies represented by a quasi-concave and weakly monotonic production function.

(A1) All actually observed input–output combinations are feasible. An input–output bundle (x, y) is feasible when the output bundle y can be produced from the input bundle x, suppose we have a sample of N DMUs from an industry producing m outputs from n inputs. Let $x_j = (x_{ij}, x_{2j}, \ldots, x_{nj})$ be the input (vector) of DUM j (j =1,2,...,N) and yj $=(y_{1j}, y_{2j}, \ldots, y_{mj})$ be its observed output (vector). Then, by (A1) each (x_j, y_j)(j =1,2,...,N) is a feasible input–output bundle.

(A2) The production possibility set is convex. Consider two feasible input–output bundles (x^A, y^A) and (x^B, y^B). Then, the (weighted) average input–output bundle$(\bar{x}, \bar{y})$, where $\bar{x} = \lambda x^A + (1-\lambda)x^B$ and $\bar{y} = \lambda y^A + (1-\lambda)y^B$ for some λ satisfying $0 \le \lambda \le 1$, is also feasible.

(A3) Inputs are freely disposable. If (x0, y0) is feasible, then for any $x \geq x0$,(x,y0) is also feasible.

(A4) Outputs are freely disposable. If (x0, y0) is feasible, then for any $y \leq y0$, (x0,y) is also feasible.

Additionally, if CRS is assumed,

(A5) If (x, y) is feasible, then for any $k \geq 0$, (kx, ky) is also feasible.

It is possible to empirically construct a production possibility set satisfying assumptions (A1–A5) from observed data without any explicit specifications of a production function.

As mentioned in 3.2, efficient frontier can be considered in two directions depending on the defining of production set. If a production set is defined in an input space, the efficient frontier is characterized by input isoquant frontier. In this direction, an approach for measuring technical efficiency is called input-oriented approach. Under the input-oriented approach, an objective is to proportionally decrease the required inputs to the extent possible while the output is held constant at some levels. On the contrary, if a production set is defined in an output space, the efficient frontier is characterized by output isoquant frontier. This approach for measuring technical efficiency is called output-oriented approach. Under the output-oriented approach, an objective is to proportionally increase the required outputs as much as possible while the input level is held constant. Generally the choice between these two approaches depends on whether inputs or outputs are controllable. Generally, the difference between these approaches depends on the extent to which inputs or outputs are controllable. However, these options estimate similar production frontier and identify the same set of efficient DMUs while the difference in efficiency score only occurs with inefficient DMUs (Coelli, 1996).

3.4.1 Data Envelopment Analysis Model

At present, DEA, with its various models, actually encompasses a number of alternate approaches to efficiency measurement. These various models are classified by a range of criteria such as the type of envelopment surface, efficiency measurement, orientation or focus, and the effect of scale changes. In this study, the difference models with respect to the type of envelopment surface are discussed.

Basically, there are two main types of a DEA model according to the assumption on envelopment surface: a Constant Return to Scale (CRS) called DEA-CCR model (named after Charnes, Cooper, and Rhodes) and a Variable Return to Scale (VRS) called DEA-BCC model (named after Banker, Charnes and Cooper). The appropriateness of a particular envelopment surface is frequently determined by economic and other assumptions regarding the data set to be analysed (Fried et al., 1993). The choice involves a selection of the particular DEA mathematical programming model.

3.4.1.1 DEA-CCR Model

The DEA-CCR Model is a basic DEA model originally proposed by Charnes et al. (1978). This model allows input-reducing and output-increasing orientations. Moreover, it imposes three restrictions on the frontier technology: CRS, convexity of the set on feasible input-output combinations; and strong disposability of inputs and outputs

As earlier mentioned, DEA is applied to measure the relative efficiency of a DMU by comparing it with a group of DMUs transforming the same group of measurable inputs into the same types of measurable outputs. Then, the group of DMUs is used to evaluate the relative efficiency. Note that all DMUs are considered homogenous in the sense that they have the same types of inputs and outputs. They are also independent, i.e. the input and output levels may assume any levels for different unit DMUs. The group of DMUs can be depicted in Figure 3.5. Suppose there are N DMUs: DMU 1, DMU 2, ..., and DMU N. Each DMU employs n inputs to produce m outputs.

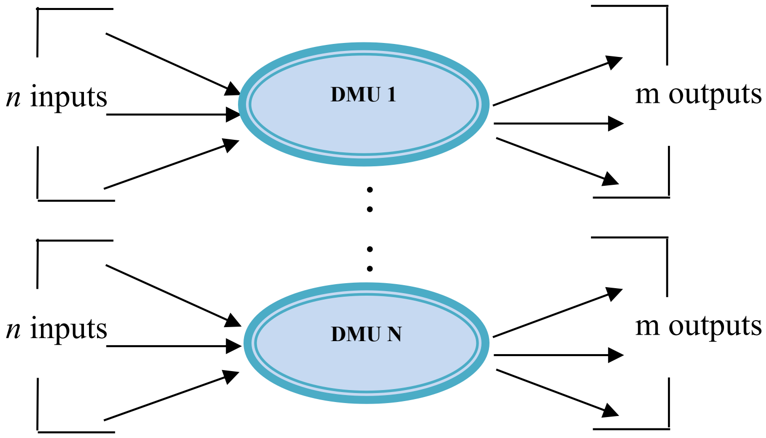


Figure 3.5 Homogeneous and Independent DMUs

Some common inputs and outputs for each of these j=l, ..., N DMUs are selected as follows (Cooper, et al., 2007): 1) numerical data are available for each input and output, with the data being assumed positive for all DMUs; 2) the inputs, outputs and choices of DMUs should reflect an analyst's or a manager's interest in the components that enter into the relative efficiency evaluations of DMUs; 3) in principle, smaller input amounts are preferable while larger output amounts are preferable so the efficiency scores should reflect these principles; and 4) the measurement units of different inputs and outputs need not be congruent, some may involve number of persons, or areas of floor space, money expended, etc.

In the DEA-CCR model, multiple inputs and outputs are linearly aggregated using weights to construct a virtual input and a virtual output for the purpose of circumvention the problem of measuring technical efficiency in case of multiple inputs and outputs with no market price. Thus, the virtual input of a DMU is obtained as the linear weighted sum of all its inputs: virtual input = $\sum_{i=1}^{n} \mu_i x_i$, where μ_i is the weight assigned to input $x_i (i = 1, \ldots, n)$. Similarly, the virtual output of a firm is obtained as the linear weighted sum of all its outputs: virtual output = $\sum_{r=1}^{m} \vartheta_r$, where ϑ_i is the weight assigned to output $y_r (r = 1, \ldots, m)$.

According to these virtual inputs and outputs, absolute efficiency of a DMU in converting the inputs to outputs is termed as the ration of virtual output to virtual input. So the absolute efficiency of DMU t can be defined as:

$$H_t(\mu_t, \vartheta_t) = \frac{\sum_{r=1}^{m} \vartheta_{rt} y_{rt}}{\sum_{i=1}^{n} \mu_{it} x_{it}}. \tag{3.1}$$

Consider N different DMUs, it may be rational to compare absolute efficiency of DMU t with the best DMU having the highest efficiency score to obtain the relative efficiency of DMU t as follows:

$$h_t(\mu_t, \vartheta_t) = \frac{H_t(\mu_t, \vartheta_t)}{H^*(\mu_t, \vartheta_t)}, \tag{3.2}$$

$$\text{where} \quad H^*(\mu_t, \vartheta_t) = \max_j = H_j(\mu_t, \vartheta_t) \tag{3.3}$$

Clearly, the same weight μ_t, ϑ_t must be used for all DMUs and, the value of relative efficiency is less than or equal to one.

In general, to determine such weights is often difficult because the quantities of inputs and outputs may be expressed in different measure units. Otherwise, each DUM's manager would try to assign the weight value in a way to get the highest efficiency. DEA model surmounts these difficulties by taking a weight that is the most favourable for each DMU, as it is outlined in the next paragraph.

To measure the relative efficiency of each DMU, the N optimization is performed, one for each DMU. Let the DMUj be evaluated on any trial and be designated as DMUt where t ranges over 1, 2, ..., N. The weights assigned to inputs and outputs of DMU t are chosen by linear programming techniques in such a way to maximize the relative efficiency (h_t), as it is expressed by equation (3.2) subject to equation (3.3) as follows:

Optimization Problem (3.4)

$$\text{Maximize} \quad h_t = \left(\frac{\sum_{r=1}^{m} \vartheta_{rt} y_{rt}}{\sum_{i=1}^{n} \mu_{it} x_{it}}\right)/H^* \tag{3.4a}$$

$$\text{Subject to} \quad \frac{\sum_{r=1}^{m} \vartheta_{rt} y_{rj}}{\sum_{i=1}^{n} \mu_{it} x_{ij}} \leq H^*; \forall j=1, \ldots, t. \ldots, N. \tag{3.4b}$$

In order to prevent the possibility of disregarding inputs or outputs that could be too unfavourable for DMU t, strictly positive values of the weight assigned to inputs or outputs are imposed as follows:

$$\vartheta_{rt}, \mu_{it} > 0; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n. \tag{3.4c}$$

Note that, the optimization problem (3.4), including equation (3.4a), (3.4b), and (3.4c), has multiple solutions, for instance, if h_t, ϑ_{rt}, μ_{it}, and H^* are the solution of (3.4), then h_t, $\alpha\beta\,\vartheta_{rt}$, $\alpha\mu_{it}$, and βH^* solve the problem (3.4), as well.

Therefore, additional constraint that imposes 1 as an upper bound to efficiency score is introduced into problem (3.4).

In this way, 1 is the value of the most efficient DMU: $H^* = 1$ in (3.4b). By virtue of these constraints, the optimal objective value $\square_t^*$ is at most 1. According to Farrell's measures of technical efficiency (a distance measures of technical efficiency), as mentioned in section 3.2, the DMUs having the (relative) efficiency score of 1 implies that they are on the efficient frontier. These DMUs are treated as the benchmark for inefficient DMUs.

As a result, the optimization problem (3.4) becomes:

Optimization Problem (3.5)

$$\text{Maximize} \qquad h_t = \left(\frac{\sum_{r=1}^{m} \vartheta_{rt} y_{rt}}{\sum_{i=1}^{n} \mu_{it} x_{it}}\right) \tag{3.5a}$$

$$\text{Subject to} \qquad \frac{\sum_{r=1}^{m} \vartheta_{rt} y_{rj}}{\sum_{i=1}^{n} \mu_{it} x_{ij}} \leq 1; \forall j=1, \ldots, t. \ldots, N. \tag{3.5b}$$

$$\vartheta_{rt}, \mu_{it} > 0; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n. \tag{3.5c}$$

From the optimization problem (3.5), the efficiency of DMUt (h t) is measured as a weighted sum of outputs divided by a weighted sum of inputs. The optimal value of DMU t's efficiency score (h_t^*) is solved by finding the optimal values of input weight (μ_{it}^*) and output weight (ϑ_{rt}^*) to maximize equation (3.5a) subject to certain constraints: (3.5b), (3.5c).

The constraint (3.5b) states that weights are universal, implies that the weights used by DMUt when applied to each DMU in the data set cannot produce an efficiency score exceeding unity, in other words, the efficiency score of all DMUs are bounded above by 1. From this constraint, it is important to note that these weights are endogenously chosen in order to maximize the efficiency of DMUt in comparison to the other DMUs which must also hold the same weight. The constraint (3.5b) states that weights on outputs and inputs are strictly positive to avoid the possibility of ignoring inputs or outputs that could be too unfavourable for DMUt.

However, the optimization problem (3.5) is a fractional programming problem which is quite difficult to solve. A simple solution for this complexity is transformation of the optimization problem (3.5) into a linear programming problem using the method of Charnes and Cooper (1962). In the first step of Charnes and Cooper (1962)'s transformation, the weighted vectors applied to input and output vector (μ_{it}, ϑ_{rt}) are multiplied by a nonnegative scale factor k which neither affect the objective function nor the constraints of that problem. Define wit = $k\mu_{it}$ and prt = $k\vartheta_{rt}$, then, the optimization problem becomes:

Optimization Problem (3.6)

$$\text{Maximize} \quad h_t = \frac{\sum_{r=1}^{m} p_{rt} y_{rt}}{\sum_{i=1}^{n} w_{it} x_{it}} \tag{3.6a}$$

$$\text{Subject to} \quad \frac{\sum_{r=1}^{m} p_{rt} y_{rj}}{\sum_{i=1}^{n} w_{it} x_{ij}} \leq 1; \; j=1, \ldots, t. \ldots, N \tag{3.6b}$$

$$p_{rt}, w_{it} \geq 0; \; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n. \tag{3.6c}$$

After that, factor k is set as follow: (a) if the approach to measuring technical efficiency is an input-oriented which is minimizing the weighted sum of inputs and holding outputs constant, $k = \frac{1}{\sum_{i=1}^{n} \mu_{it} x_{it}}$, then $\sum_{i=1}^{n} w_{it} x_{it} = 1$; and (b) if the approach to measuring technical efficiency is an output-oriented which is maximizing the weighted sum of outputs and holding inputs constant, $k = \frac{1}{\sum_{r=1}^{m} \vartheta_{rt} y_{rt}}$, then $\sum_{r=1}^{m} p_{rt} y_{rt} = 1$. Therefore, the primal problems of each approach are given below:

Input-oriented approach: primal problem (Model 3.7)

$$\text{Maximize} \quad \sum_{r=1}^{m} p_{rt} y_{rt} \tag{3.7a}$$

$$\text{Subject to} \sum_{r=1}^{m} p_{rt} y_{rj} - \sum_{i=1}^{n} w_{it} x_{ij} \leq 0 \; ; j=1, \ldots, t. \ldots, N \tag{3.7b}$$

$$\sum_{i=1}^{n} w_{it} x_{it} = 1 \tag{3.7c}$$

$$p_{rt}, \; w_{it} \; \geq \; 0; \; \forall r = 1,\ldots, m, \; \forall i = 1,\ldots, n \tag{3.7d}$$

Output-oriented approach: primal problem (Model 3.8)

$$\text{Minimize} \quad \sum_{r=1}^{m} w_{it} x_{it} \tag{3.8a}$$

$$\text{Subject to} \sum_{r=1}^{m} p_{rt} y_{rj} - \sum_{i=1}^{n} w_{it} x_{ij} \leq 1 \; ; j=1, \ldots, t. \ldots, N \tag{3.8b}$$

$$\sum_{i=1}^{n} p_{rt} y_{rt} = 1 \tag{3.8c}$$

$$p_{rt}, w_{it} \geq 0; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n \tag{3.8d}$$

However, in practice, dual (the equations for each approach are given below) is often used in computation since it is more tractable than the primal, with only m+n constraints rather than the N+1 constraints of the primal.

Input-oriented approach: dual problem (Model 3.9)

Minimize θt (3.9a)

Subject to $y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} \leq 0;\ \ r = 1, \ldots, m$ (3.9b)

$\theta_t\, x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} \geq 0;\ \ i = 1, \ldots, n$ (3.9c)

$\lambda j \geq 0;\ \ \forall j = 1, \ldots, N$ (3.9d)

Output-oriented approach: dual problem (Model 3.10)

Maximize ϕt (3.10a)

Subject to $\phi_t y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} \leq 0;\ \ r = 1, \ldots, m$ (3.10b)

$x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} \geq 0;\ \ i = 1, \ldots, n$ (3.10c)

$\lambda j \geq 0;\ \ \forall j = 1, \ldots, N$ (3.10d)

From the above linear programming problem, the role of slacks in measuring efficiency is ignored. The problem of slacks arises because of the sections of the efficiency boundary which run parallel to the vertical and horizontal axes (GA and DH in Figure 3.6).

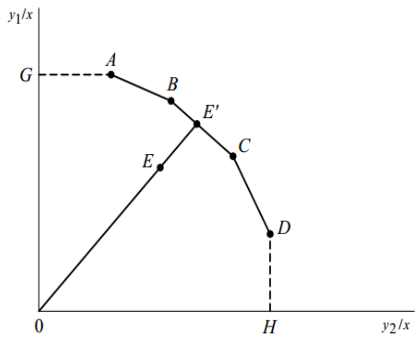


Figure 3.6 Graphical Representation of DEA (output-oriented approach) with Slacks

Suppose an additional DMU, F, is included in the data set, and its position on Figure 3.6 is on the line segment DH. It would lie on the boundary and would therefore have an efficiency score of 1. Yet there would exist of another DMU in the data set, namely DMU D, which is producing the same level of output y2 and more of output y1 relative to the same quantity of input. DMU F could, hence, increase its efficiency in terms of one of the outputs (y1), and so there is said to be output slack. It is also possible for input slack to exist where it is possible to decrease the quantity of at least one of the inputs without altering the level of output(s) produced. The above equations can therefore be rewritten with output and input slacks (represented by sr and si, respectively):

Input-oriented approach (CRS): dual problem
with output and input slack (Model 3.11)

Minimize $\theta_t - \varepsilon \sum_{r=1}^{m} s_r - \varepsilon \sum_{r=1}^{n} s_i$ (3.11a)

Subject to $y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0;\ r = 1, \dots, m$ (3.11b)

$\theta_t\, x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0;\ i = 1, \dots, n$ (3.11c)

$\lambda_j, s_r, s_i \geq 0;\ \forall j = 1, \dots, N$ (3.11d)

Output-oriented approach (CRS): dual problem
with output and input slack (Model 3.12)

Maximize $\emptyset_t + \varepsilon \sum_{r=1}^{m} s_r + \varepsilon \sum_{r=1}^{n} s_i$ (3.12a)

Subject to $\phi_t y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0;\ r = 1, \dots, m$ (3.12b)

$x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0;\ i = 1, \dots, n$ (3.12c)

$\lambda_j, s_r, s_i \geq 0;\ \forall j = 1, \dots, N$ (3.12d)

Thus, DMUt is efficiency if the efficiency score TEt = θt = 1 (equivalently, TEt = 1/ϕt = 1) and the slack sr and si = 0, ∀r =1, …, m and ∀i = 1, …, n. These efficiency score are based on the definition of efficiency which involves two types of DMUs: observed and virtual units. The virtual units have efficiency score equal to 1 to be considered as efficient units while the remaining units have a score of less than 1, representing the distance of these units from the efficient frontier.

3.4.1.2 DEA-BCC Model

As presented above, the DEA-CCR model measures technical efficiency of a DMU related to a group of DMUs on the production frontier exhibiting CRS assumption. Under this assumption, all evaluated DMUs are performing at an optimal scale, and are able to linearly scale the inputs and outputs without increasing or decreasing efficiency, implying that there is no significant relationship between their scale and efficiency. That is, large DMUs are just as efficient as small ones in converting inputs to outputs. Moreover, input minimization and output maximization produce the same relative efficiency scores, provided all inputs are controllable.

However, in the real world, this optimal behaviour is often precluded by a variety of circumstances such as different types of market power, constraints on finances, externalities, imperfect competitions, etc. (Coelli, Rao, O'Donnell, & Battese, 2005). As a result, the DEA-CCR model should not be applied in a wide variety of situations. In addition, this CRS assumption yields misleading measures of technical efficiency in the sense that technical efficiency scores reported under a set of constraints are biased by scale efficiencies (Avkiran, 2001). In other word, the CRS assumption distorts the results of comparison among DMUs whose size is significantly different. In this situation, it is important to know how the scale of production affects the efficiency score. This important shortcoming is corrected by Banker, Charnes, and Cooper (1984) who extended DEA to the case of VRS, which permits not only constant but also increasing and decreasing returns to scale at different scale sizes. The modified model is called DEA-BCC model, named after Banker, Cooper, and Rhodes.

The BCC model is quite similar to the above indicated CCR model. The difference is an addition of a convexity constraint to the system: $\sum_{j=1}^{N} \lambda_j = 1$, for j = 1,…, N. This constraint simply guarantees that each DMU is only compared to others of similar size or in the same region of return to scale. Such mode of operation avoids damaging effect of scale efficiency on the technical efficiency scores (Murillo-Zamorano, 2004).

3.5 Scale Efficiency

In accordance with Coelli et al. (2005), under VRS assumption, an evaluated DMU may be too small in its scale of operation which might fall within the increasing returns to scale (IRS) part of the production frontier. Similarly, an evaluated DMU may be too large and may operate within the decreasing returns to scale (DRS) part of the production frontier. In both cases, efficiency of DMUs might be improved by changing their scale of operations, i.e., to keep the same input mix but change the size of operations. This implies that scale size of production affects the productivity of a DMU.

Some important questions arise in respect of the scale size at which a DMU operates. For example, is there a scale size that would be optimal in some sense for the DMU? How far the scale size of a unit is away from optimal? These Questions are captured in the concepts of Most Productive Scale Size (MPSS), and scale efficiency.

An optimal scale size to operate at is where CRS holds. This optimal scale size is defined as MPSS, termed by Banker (1984), with reference to a specific mix of inputs and outputs. In a single input/single-output framework, MPSS is offered by the unit(s) offering maximum average product or output-input ratio. A distance of the scale size of a DMU from MPSS is reflected in its scale efficiency. This measure is defined in either an input or an output orientation as the ratio between technical (i.e., CRS) efficiency and pure technical (i.e., VRS) efficiency, that is,

$$\text{Scale input (output) efficiency of } DMU_0 = \frac{\text{CRS technical efficiency of } DMU_0}{\text{VRS input (output) technical efficiency of } DMU_0}$$

As showed above, the technical efficiency (CRS technical efficiency) of a DMU can never exceed its pure technical efficiency (VRS technical efficiency) in either orientation. Thus, from the definition of scale efficiency above, scale efficiency can never be greater than 1.

Another way to see scale efficiency is as a measure of the distance between CRS and VRS boundaries at the scale size of a unit. Scale efficiency is explained through Figure 3.7 as follows. CRS production frontier (the dashed line) and VRS production frontier (the solid line) are drawn for a situation where there are only one input and one output. Consider DMU B, for example which has an output-oriented technical efficiency equal to the ratio OO1/OO2 under VRS production frontier which is higher than OO1/OO3, the output-oriented technical efficiency under CRS production frontier. In other words, the output-oriented technical inefficiency of DMU B is higher when a CRS rather a VRS assumption exhibits. In addition, this is true irrespective of orientation and for all possible production points inside or on the VRS production frontier, with an exception of point C (where the two measures are identical). Obviously, the VRS production frontier takes the magnitude of scale efficiency into account when measuring the aggregate technical efficiency. As a result, the scale efficiency of DMU B in output orientation is OO2/OO3.

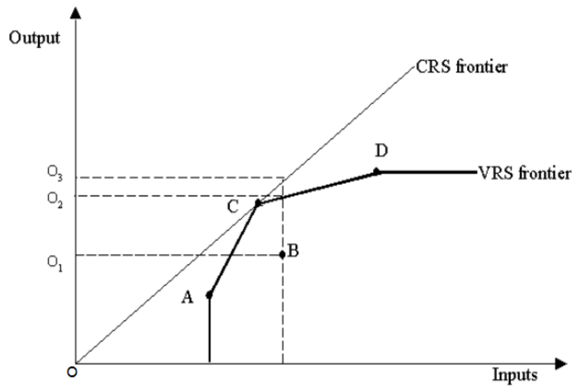


Figure 3.7 DEA Frontiers: Constant and Variable Returns to Scale
Source: Banker, 1984.

The global measures of technical efficiency (measured in relation to the CRS production frontier) are therefore a composite of pure technical efficiency and scale efficiency. With reference to figure 3.8, global technical efficiency: TECRS=OO1/OO3 = (OO1/OO2)×(OO2/OO3) is equivalent to TECRS = TEVRS× SE(scale efficiency). In other word, the technical efficiency score of a DMU obtained from CCR model can be decomposed into two elements: pure technical efficiency and scale efficiency (SE). According to Cooper et al. (2007), this decomposition, which is unique, depicts the sources of inefficiency, i.e. whether it is caused by inefficient operation (pure technical efficiency) or by disadvantageous conditions revealed by the scale efficiency or by both. The larger the divergence between VRS and CRS efficiency scores, the lower the value of scale efficiency and the more adverse the impact of scale size on productivity (Fried et al., 1993)

As stated in Avkiran (2001), the decomposing technical efficiency scores into pure technical efficiency, and scale efficiency can provide guidance on what can be achieved in the short versus long term. For example, if most of the observed inefficiency is due to a small scale, that DMUs are considered expansion. However, in an organization like HEIs, this exercise can be fast-tracked through in-market mergers in case of profit-making organizations, it is a much more bureaucratic and lengthy process for HEIs which normally have to extensively consult key stakeholders such as Federal and State governments. On the other hand, pure technical inefficiency can often be addressed in a shorter time period.

Although, this decomposing discovers an existing scale of production and scale efficiency in each DMU, its usefulness is limited, as it only demonstrated the existence of scale efficiency without suggestion the nature of its return to scale (RTS) which is the valuable information for managerial decision making. For example, if IRS holds at an efficient production point, raising its input levels by a small percentage will lead to an expansion of its output levels by larger percentage, assuming that the unit remains efficient. Obviously, it makes sense for a DMU operating at a point where IRS holds to increase its scale size, if this is under its control, because its additional input requirements may be more compensated by a rise in output levels. Similarly, a DMU operating at a point where DRS assumption holds should decrease its scale size.

3.6 Identifying the Nature of Return to Scale

As mentioned in section 3.1.5, scale efficiency falls below unity at any points on the VRS production frontier that is not an MPSS. This is true under both increasing and diminishing returns to scale. Thus, scale efficiency by itself reveal nothing about the nature of returns to scale.

There are three basic methods of testing DMUs' RTS nature appeared in the DEA literature (Seiford & Zhu, 1999): 1) CCR-RTS method, developed by Banker (1984), 2) BCC-RTS method, developed by Banker et al. (1984), and 3) scale efficiency index method, developed by Färe and Grosskopf (1985). These three RTS methods, in fact, are equivalent but different presentations. However, it has been noted that CCR and BCC RTS methods may fail when DEA models have alternate optima, i.e. the original CCR and BCC RTS methods assume unique optimal solutions to the DEA formulations. In contrast to the CCR and BCC RTS methods, the scale efficiency index method does not require any information on the primal and dual variables. Particularly, it is robust even when multiple optima exist since it may be impossible or at least unreasonable to generate all possible multiple optima in many real world applications.

3.6.1 CCR-RTS Method

This first method uses a sum of optimal values of the λs when the CCR model is solved. Consider a set of DMUs (j = 1, . . . , N) operating under CRS and let DMU0 be Pareto-efficiency technical efficient. Solve the CCR model without the convexity constraint (model 3.11 or 3.12) with respect to DMUo, and let the superscript * to a variable denote its optimal value.

Input-oriented approach (CRS): dual problem
with output and input slack (Model 3.11)

Minimize $\theta_t - \varepsilon \sum_{r=1}^{m} s_r - \varepsilon \sum_{r=1}^{n} s_i$ (3.11a)

Subject to $y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0; \;\; r = 1, \dots, m$ (3.11b)

$\theta_t \, x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0; \;\; i = 1, \dots, n$

(3.11c)

$\lambda_j, s_r, s_i \geq 0; \;\; \forall j = 1, \dots, N$ (3.11d)

Output-oriented approach (CRS): dual problem
with output and input slack (Model 3.12)

Maximize $\emptyset_t + \varepsilon \sum_{r=1}^{m} s_r + \varepsilon \sum_{r=1}^{n} s_i$ (3.12a)

Subject to $\phi_t y_{rt} - \sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0; \;\; r = 1, \dots, m$ (3.12b)

$x_{it} - \sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0; \;\; i = 1, \dots, n$ (3.12c)

λj, sr, si ≥ 0; ∀j = 1, …, N (3.12d)

Condition

1) If $\sum_{j=1}^{N} \lambda_j^* = 1$, for at least one optimal solution, CRS holds locally at DMU0

2) If $\sum_{j=1}^{N} \lambda_j^* \geq 1$, for all optimal solutions, DRS holds locally at DMU0

3) If $\sum_{j=1}^{N} \lambda_j^* \leq 1$, for all optimal solutions, IRS holds locally at DMU0

3.6.2 BCC-RTS Method

Consider a set of DMUs (j = 1, . . . , n) operating under VRS. Solve the input-oriented model 3.13 with respect to DMU0 and let DMU0 be technical efficient:

Input-oriented approach (VRS): primal problem (Model 3.13)

Maximize $\sum_{r=1}^{m} p_{r0} y_{r0} + \omega$ (3.13a)

Subject to $\sum_{r=1}^{m} p_{r0} y_{rj} - \sum_{i=1}^{n} w_{i0} x_{ij} + \omega \leq 0$; j=1, …, t. …, N (3.13b)

$\sum_{i=1}^{n} w_{i0} x_{i0} = 1$ (3.13c)

$p_{rt}, w_{it} \geq 0; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n$ (3.13d)

Condition

1) If ω takes negative values in all optimal solutions to model 14, DMU_0 DRS is held locally.

2) If ω takes a zero value in at least one optimal solution to model 14, at DMU_0 CRS is held locally.

3) If ω takes positive values in all optimal solutions to model 14, DMU_0 IRS is held locally.

For output-oriented models, solve model 3.14 with respect to DMU0 and let DMU0 be Pareto-efficient:

Output-oriented approach (VRS) : primal problem (Model 3.14)

Minimize $\sum_{r=1}^{m} w_{i0} x_{i0} + \omega$ (3.14a)

Subject to $\sum_{r=1}^{m} p_{r0} y_{rj} - \sum_{i=1}^{n} w_{i0} x_{ij} + \omega \leq 0$; j=1, …, t. …, N (3.14b)

$\sum_{i=1}^{n} p_{r0} y_{r0} = 1$ (3.14c)

$p_{rt}, w_{it} \geq 0; \forall r = 1,\ldots, m, \forall i = 1,\ldots, n$ (3.14d)

Condition

1) If ω takes negative values in all optimal solutions to model 15, DMU_0 IRS is held locally.

2) If ω takes a zero value in at least one optimal solution to model 15, DMU_0 CRS is held locally.

3) If ω takes positive values in all optimal solutions to model 15, DMU0 DRS is held locally.

3.6.3 Scale Efficiency Index Method

This approach requires three efficiency measures, respectively, in relation to three technological return-to-scale specifications: CRS, VRS, and NIRS. From the efficiency measures obtained from each of these models, conclusions can be reached concerning returns to scale:

1) If the CRS, VRS, and NIRS models yield exactly the same efficiency measure, the unit lies, or is projected, on a boundary region exhibiting local CRS.

2) If the CRS and NIRS efficiency measures are both equal and lower than the VRS efficiency measure, the unit lies, or is projected, on an IRS region of the boundary.

3) If VRS and NIRS efficiency measures are both equal and higher than the CRS efficiency measure, the unit lies, or is projected, on a DRS region of the boundary.

According to Seiford and Zhu (1999); Färe and Grosskopf (1985)'s method has an advantage of being unaffected by the existence of multiple optimal solutions. However, its main disadvantage seems to be the need to solving three DEA problems.

3.7 Previous Studies on Higher Education Institutions Efficiency Measurement Using DEA

To this point, the definition of technical efficiency and the techniques for measuring technical efficiency have been introduced. Now, the attention is turned to briefly reviewing the studies on HEIs' efficiency measurement using DEA that have been undertaken over the past decade. The use of DEA to assess the efficiency of DMUs in an education sector attracts the most attention in the early days of its development in 1987. This is probably because Charnes, who firstly introduced DEA, applied it to evaluate the efficiency of the program follow through, which is a large-scale experiment in public school education (Liu et al., 2013).

According to the ability of DEA in measuring the performance of non-profit organization producing multiple outputs from multiple inputs with the absence of market price (for both inputs and outputs), DEA application in studies on HE sector has been achieved through a widespread use in practice (Johnes, 2006b). However, the DEA application within HE context is relatively new and undersized in comparison to its totality. Although DEA technique is useful, its application in HE context is less than 4% of the DEA articles published in scientific journals over the period 1950-2007 (Wolszczak-Derlacz & Parteka, 2011).

In this section, the existing empirical on HEIs' efficiency is reviewed accoording to the following methodologies issues: unit of analysis, analysis options in DEA (orientation and DEA-model), model development, and iuputs/outputs specification.

3.7.1 Unit of Analysis

In HE context, studies on efficiency measurement have attempted to evaluate performance in various levels as follows: the HEIs in one country and more than one country, the same department or unit across different HEIs, different departments or units within one HEI, and the individual student level.

The studies that based on cross sectional data at an institutional level in one country are a major part of the existing literatures as shown in Table 3.2, albeit there are small samples of countries having been covered. For example, Australia (e.g., Avkiran, 2001; Abbott & Doucouliagos, 2003; Wortington & Lee, 2008; Lee, 2011), the UK (e.g., Athanassopoulos & Shale, 1997; Flegg, Allen, Field, & Thurlow, 2004; Johnes, 2006a; Johnes, 2008), Canada (e.g., McMillan & Datta,1998), China (e.g., Ng & Li, 2000; Johnes & Li, 2008), Netherlands (e.g., Cherchye & Abeele, 2005; Groot & Gracia-Valderrama, 2006), Germany (e.g., Warning, 2004; Kempkes & Pohl, 2010;

Katharaki & Katharaki, 2010), the US (e.g., Eckles, 2010; Sav, 2012; Sav, 2013), Italy (e.g., Agasisti & Salerno, 2007), Bulgaria (Tochkov, Nenovsky, & Tochkov, 2012), Portugal (e.g., Cunha & Rocha, 2012), the Philippines (e.g., Castano & Cabanda, 2011). Note that for the review of more earlier empirical studies utilising DEA to measure efficiency in HE context, see Worthington (2001) and Johnes (2004).

Unfortunately, there exist only few studies applying DEA to investigate HEIs efficiency in developing countries. In case of Thailand, to the best of the author's knowledge, there are only two studies. The first is the study of Kantabutra and Tang (2010) which investigate the performance of 22 Thai public universities during 2003-2006 in terms of efficiency where two efficiency models: the teaching efficiency model and the research efficiency model, are developed and the analysis is conducted at the faculty level. The second is the study of Wongchai, Liu, and Peng (2012) which examines the regional differences in technical efficiency of the 77 national universities by using a meta-frontier model estimated by DEA to calculate the comparable technical efficiencies for firms operating under different technologies.

Concerning the international perspective, there are few studies scrutinizing the differences of HEIs' efficiency across counties. Agasisti and Johnes (2009); Agasisti and Perez-Esparrells (2010); Agasisti and Pohl (2012) respectively compare the efficiency of Italian universities to those in the U.K., Spain, and Germany. However, these authors admit themselves that comparing between the performances of HEIs in only two countries provides no general conclusions. Bonaccorsi and Daraio (2007) previously cover universities in Italy, Spain, Portugal, Norway, Switzerland and the UK while Bonaccorsi, Daraio, Räty, and Simar (2007) compare universities by research field in Finland, Italy, Norway and Switzerland. Later, Aubyn, Garcia, and Pais (2009) compare the efficient of public HEIs in the EU Member States with public HEIs in Japan and the US. Wolszczak-Derlacz and Parteka (2011), analyse institutions in seven European countries for the period 2001 to 2005. Unlike his previous studies, Wolszczak-Derlacz (2014) compare the efficiency of European HEIs with U.S. counterparts or examine the differences in performance measured over a 10-year period taking into account cross-country and cross-unit heterogeneity.

University panel data in DEA have been used. Clearly, there appears to be few studies that have utilized the panel data in exploring HEIs' efficiency and productivity changes over time via the Malmquist index, such as Flegg et al. (2004); Castano and Cabanda (2011); Johnes (2008); Wothington and Lee (2008); Agasisti and Johnes (2009); Kempkes and Pohl (2010); Agasisti and Pohl (2012); Sav (2013); Wolszczak-Deelacz (2014).

Apart from the cross sectional studies regarding institutional level, there are some studies investigating HEIs' efficiency at a micro department or program level. These studies are: Beasley (1995) investigating the efficiency of chemistry and physics departments within 52 United Kingdom universities in the 1986 (i.e., 1986-87) academic year, Casu and Thanassoulis (2006) examining the efficiency of 118 university libraries in the U.S. and the central administration in 108 United Kingdom universities; Colbert, Levary, and Shaner (2000), a 1997 cross section of 24 MBA programs in United States, whereas Sinuany-Stern et al. (1994) concentrating on a single university, Ben Gurion, through its data and apply DEA to 21 different departments. Other explorations include the top 24 ranked MBA programs in the United States examined by Colbert, et al. (2000), a sample of 18 research units at the Helsinki school of economics (Korhonen, Tainio, & Wallenius, 2001), the 78 research programs organized at 8 Dutch universities in 1996-2000 in the Cherchye and Abeele (2005) study, and the 169 Dutch research groups in economics, econometrics and business administration in 1995 and 2001, by Groot and Gracia-Valderrama (2006). Given the diversity of these studies, there exists a wide range of efficiency estimates; overall from 0.18 to 0.92 for the minimum efficiency scores. This difference in efficiency scores has positive relationship to the potentially heterogeneity of evaluated units. In an individual level, there is the study of Joumady and Ris (2005) which investigates the efficiency of HEIs in providing competencies to graduates and in matching competencies provided during the study period to competencies required on the labour market among a large sample of young graduates interviewed three years after graduation from 8 European countries and 209 HEIs.

3.7.2 Analysis Options in DEA

As mentioned in 3.7.1, the scope of most empirical studies on HEIs' efficiency, with only few exceptions, is limited to the HEIs of a country, but analysis options in DEA are varied.

The first analysis option is the appropriate approaches for measuring efficiency which are input-oriented and output-oriented approach. Selecting an appropriate orientation is not as crucial as it is in case of econometric estimation (Coelli et al., 2005). However, in HE sector, the HEIs may be given a fixed quantity of resources (e.g., public financial resources, students enter qualification) and asked to produce as much output as possible. This implies that input environmental of HE sector, especially public HEIs, is relatively inflexible.

As a result, the majority of empirical studies on HEIs' efficiency mainly relies on an output-oriented approach. However, some studies have applied input-oriented approach such as Athanassopoulos and Shale (1997); McMillan and Datta (1998); Colbert et al. (2000); Abbott and Doucouliagos (2003); Groot and Gracia-Valderrama (2006); Castano and Cabanda (2011); Katharaki and Katharakis (2010); Lee (2011); Cunha and Rocha (2012); Tochkov et al. (2012).

The second one is the choice between CCR and BCC DEA-model. In CCR DEA-model, the assumption of CRS holds. This model is suitable only when all HEIs are operating at an optimal scale, if not, technical efficiency score will be confounded with scale efficiency. This condition is not appropriate in real-life situation especially in the context of large public-sector organizations. The CRS assumption can be relaxed and the DEA model can be easily modified to incorporate VRS. The DEA model is known as the BCC model.

Although, from the existing studies as shown in Table 3.2, there is no definitive guideline for selecting between CCR DEA-model and BCC DEA-model, the empirical studies on HEIs' efficiency mainly apply to the BCC DEA-model for analysing HEIs' efficiency. Only some studies have used the CCR DEA-model, such as Warning (2004); Groot and Gracia-Valderrama (2006); Katharaki and Katharakis (2010); Wolszczak-Derlacz and Parteka (2011); Wolszczak-Derlacz (2014). Moreover, in order to decompose technical efficiency into pure technical efficiency and scale efficiency many researchers simultaneously apply both the CCR and BCC DEA-model, e.g. McMillan and Datta (1998); Avkiran (2001); Abbott and Doucouliagos (2003); Flegg et al. (2004); Agasisti and Salerno (2007); Johnes (2008); Aubyn et al. (2009); Agasisti and Johnes (2009); Agasisti & Perez-Esparrells (2010); Agasisti and Pohl (2012); Cunha and Rocha (2012); Sav (2012); Sav (2013).

3.7.3 Model Development

As HE being a sector that is supposed to produce and disseminate knowledge through two main channels (teaching and research), it is important therefore to properly define its outcomes. Generally, HE outcomes are differently measured depending on the objectives of the studies.

The majority of empirical studies as demonstrated in Table 3.2 are the combination of teaching and research outputs as educational outcomes and developed overall efficiency model (see, Athanassopoulos & Shale, 1997; McMillan & Datta, 1998; Avkiran, 2001; Abbott & Doucouliagos, 2003; Flegg et al., 2004; Warning, 2004; Johnes, 2006a; Agasisti & Salerno, 2007; Castano & Cabanda, 2011; Johnes, 2008; Worthington & Lee, 2008; Aubyn et al., 2009; Agasisti & Johnes, 2009; Katharaki & Katharakis, 2010; Agasisti & Perez-Esparrells, 2010; Kempkes & Pohl, 2010; Wolszczak–Derlacz & Parteka, 2011; Agasisti & Pohl, 2012; Sav, 2012; Sav, 2013; Wongchai et al., 2012; Wolszczak–Derlacz, 2014). Others focus only on research outputs and developed research efficiency model (Ng & Li, 2000; Korhonen et al., 2001; Cherchye & Abeele, 2005; Groot & Gracia-Valderrama, 2006; Johnes & Li, 2008) or focused only on teaching outputs and developed teaching efficiency model (Colbert et al, 2000; Eckles, 2010; Cunha & Rocha, 2012; Lee, 2011). Additionally, there are some studies that separately developed both teaching and research efficiency model at the same time, such as Beasley (1995); Kantabutra and Tang (2010); Tochkov et al. (2012).

3.7.4 Inputs and Outputs Specification

Inputs/Outputs specification is an important step in DEA since the number of inputs and outputs included in any DEA affect the expected performance of efficient DMU and also affect the expected overall average efficiency. Nevertheless, the specification of inputs and outputs is often difficult. Many outputs of educational units are not measurable, such as university contributions to the third party, increasing in a students' knowledge and competency. Owing to the complications in specifying inputs and outputs for educational units, it is a very decisive to examine the results of variation in the inputs and outputs specification on efficiency scores (Johnes & Johnes, 1993). However, there exist not many empirical studies which test the sensitivity of the results to changes the specifications in DEA, such as McMillan and Datta (1998); Colbert et al. (2000); Abbott and Doucouliagos (2003); Johnes (2006a); Johnes and Li (2008); Katharaki and Katharakis (2010). Most empirical studies cited above reveal that relative efficiency score of the operating units in question, obtained by DEA, can be sensitive to the specifications of inputs and outputs.

The choice on inputs and outputs measures is another area of controversy in many DEA empirical studies. To clearly identify the inputs and outputs adopted for evaluating HEIs' efficiency, a conceptual view of what the inputs and outputs are for HEIs is required. The selection of HEIs inputs and outputs measures should be defined primarily regarding their provided outputs in term of teaching, research, consultancy and other educational services (Flegg et al, 2004). Although, there are many options for choosing inputs and outputs to DEA in HE sector, the definitive study for guiding the selection in educational applications of DEA is still not currently obtainable.

In reference to Johnes (2006a), there are two issues which need to be considered in the context of inputs and outputs specification. The first relates to the initial measurement and specification of the input and output set, and the second to the importance of each of the inputs and outputs in the DEA applications. The substantial problems in defining and measuring the inputs and outputs of HE production process are: 1) it is not actually clear what are the output of HE production process, 2) some output measures are not adequately taken in to account of the quality aspects, 3) the unavailability of adequate outputs measures leads to the use of input data to reflect output levels which violates the aim of efficiency studies in establishing the relationship between inputs and outputs to evaluate HEIs' performance. 4) the presence of mulicolinearity among the outputs, 5) the presence of mulicolinearity among the inputs arising from attempting to incorporate many inputs into studies of HEIs' efficiency, 6) some important inputs measures may be omitted, as a result of the difficulty in measuring, 7) inability to distinct between inputs which can be controlled by the HEIs under investigation, and those which cannot, such as environmental factors (See details in Johnes (2004)).

3.7.4.1 The outputs

The HEIs' outputs should be primarily categorized according to the services they provide in terms of teaching, research, and other educational services (McMillian & Datta, 1998; Avkiran, 2001; Flegg et al., 2004), thus, aspects of HEIs' activities are generally captured by means of teaching and research output.

1) Teaching Output

According to Johnes (2004), teaching output can be broken down into a number of components, all of which can be considered outputs of the education process. These include student achievement, increased productivity in the labour force, and present and future consumption benefits.

The number of students graduating or achieving a particular qualification or the number of degrees awards is a common measure of student achievement used in HEIs studies, for example, in the study of Beasley (1995); Athanassopoulos and Shale (1997); Abbott and Doucouliagos (2003); Flegg et al. (2004); Warning (2004); Johnes (2006a); Castano and Cabanda (2011); Johnes (2008); Worthington and Lee (2008); Aubyn et al. (2009); Agasisti and Johnes (2009); Kantabutra and Tang (2010); Agasisti and Perez-Esparrells (2010); Kempkes and Pohl (2010); Wolszczak-Derlacz and Parteka (2011); Agasisti and Pohl (2012); Wolszczak-Derlacz (2014). However, such output measures are not adequately taken account on the quality of achievement. Consequently, there exist few studies which use mean institution examination scores and percentage success rate as an output measure in both institutional and individual levels, for example, Johnes and Taylor (1990) and Eckles (2010) in institutional level, and Smith and Naylor (2001) in individual level.

Since the number of students graduating or achieving a particular qualification cannot indicate all skills which might be considered as outcomes of education, and is just only one of desirable outcomes of the teaching activities whereas increasing in students' productivity in labour market is, then, another aspect to reflect an additional output of teaching. Some empirical studies use graduates' employment rate (Avkiran, 2001; Kantabutra & Tang, 2010; Tochkov et al., 2012), graduates' earnings (Colbert et al., 2000; Tochkov et al., 2012), competency matching (Joumady & Ris, 2005), and employer's satisfaction (Colbert et al., 2000) as proxies of rising in students' productivity.

Additionally, HEIs also produce individuals who fail to attain a qualification. Wastage due to failure of examinations, dropping out is a by-product of the teaching process and its incidence is often concealed if numbers of successful or enrolling students, or labour market successes of graduates are used to reflect teaching output. Thus, retention rates (Avkiran, 2001) student progress rates (Avkiran, 2001), or drop-out rates (Agasisti & Salerno, 2007) have been included to reflect this aspect of teaching output in HEIs.

As a result of data constraints on the availability of adequate output measures, there is an endeavour to utilize input data for reflecting outputs level which may violate the aim of efficiency studies in establishing the relationship between inputs and outputs for the purpose of evaluating HEIs' efficiency. Surprisingly, there is a great number of empirical studies where teaching outputs is proxied by teaching inputs such as students numbers or enrolments (Beasley, 1995; Mcmillan & Datta, 1998; Avkiran, 2001; Abbott & Doucouliagos, 2003; Agasisti & Serlano, 2007; Castano & Cabanda, 2011, Katharaki & Katharakis, 2010, Cunha & Rocha, 2012; Tochkov et al., 2012; Wongchai et al., 2012; Wolszczak-Derlacz, 2014) and number of credit hours (Sav, 2012; Sav, 2013)

For the last components of teaching output, present and future consumption benefits, there is difficulty in constructing measures for the consumption benefits of education or of the other externalities from the teaching process. Accordingly, none of present empirical studies on HEIs' efficiency have satisfactorily incorporated measures of such outputs.

2) Research Output

A process of identifying and measurement of research outputs is more complicated relative to the teaching outputs. Theoretically, research outputs should comprise of the created new knowledge and the improved existing knowledge (Ahn & Seiford, 1993). However, the suitable and helpful measures of occurring knowledge in HE sector as proxies of research outputs are hard to completely obtain. Therefore, there are a number of diverge quantified measures of HEIs research outputs.

Many empirical studies use research grants, incomes, or expenditures secured by HEIs as a proxy of research output which reveals both the quality and quantity, as these measures reflects the recent market value of the research performance. Examples of those studies are: Beasley (1995); Mcmillan and Datta (1998); Flegg et al. (2004); Johnes (2006a); Agasisti and Salerno (2007); Johnes (2008); Worthington and Lee (2008); Agasisti and Johnes (2009); Katharaki and Katharakis (2010); Agasisti and Perez-Esparrells (2010); Kempkes and Pohl (2010); Lee (2011); Agasisti and Pohl (2012); Sav (2012); Sav (2013); Wongchai et al. (2012). However, there are few empirical studies classifying a research grants, incomes, or expenditures in HE sector as an input measures, for example, Athanassopoulos and Shale (1997); Korhonen et al. (2001); Johnes and Li (2008); Kantabutra & Tang (2010); Tochkov et al. (2012). The confusion in identifying these measures as either an input or output measures might generate double-counting in efficiency measurement. What is more, Johnes and Johnes (1993) have emphasized that not all research grants, incomes, or expenditures are spent for the purpose of research. Some portions are spent on research facilities, which should be identified as research input.

More satisfactory measures of research output which take into account both quantity and quality of research output include: weighted research rating derived from peer reviews (Beasley, 1995; Athanassopoulos & Shale, 1997; Avkiran, 2001; Abbott & Doucouliagos, 2003). Moreover, in the absence of peer review data, the total number of publications is an alternative choice of research output measures for investigating HEIs' efficiency (for example, Ng & Li, 2000; Korhonen et al., 2001; Warning, 2004; Groot & Gracia-Valderrama, 2006; Johnes & Li, 2008; Worthington & Lee, 2008; Aubyn et al., 2009; Wolszczak-Derlacz & Parteka, 2011; Lee, 2011; Wongchai et al., 2012; Wolszczak-Derlacz, 2014).

Moreover, in order to account for quality as well as quantity of researches, publications in "core" journal (Cherchye & Abeele, 2005; Groot & Gracia-Valderrama, 2006; Kantabutra & Tang, 2010) and citation index (Aubyn et al., 2009, and Tochkov et al., 2012) are included as research output measures to reflect the quality.

3.7.4.2 The Inputs

According to Johnes (2004), input variables used in investigating HEIs' efficiency at an institutional level can be divided into two categories: labour and human capital inputs and physical capital inputs. The human input refers to staff providing students the knowledge, and student themselves. The physical capital input refers to a wide range of products used in HEIs operations, including land, building, plant, space, and equipment.

Labour and human capital inputs in the education production process are often measured by staff numbers in terms of Full Time Equivalent (FTE). Normally, the HEIs staff can be divided into two types: academic staff and non-academic staff. This measures has been commonly employed in many empirical studies on HEIs' efficiency for example, Athanassopoulos and Shale (1997); Ng and Li (2000); Avkiran (2001); Abbott and Doucouliagos (2003); Flegg et al. (2004); Cherchye and Abeele (2005); Johnes (2006a); Groot and Gracia-Valderrama (2006); Agasisti and Salerno (2007); Castano and Cabanda (2011); Johnes (2008); Worthington and Lee (2008); Aubyn et al. (2009); Agasisti and Johnes (20090; Kantabutra and Tang (2010); Katharaki and Katharakis (2010); Agasisti and Perez-Esparrells (2010); Eckles (2010); Kempkes and Pohl (2010); Wolszczak-Derlacz and Parteka (2011); Lee (2011); Agasisti and Pohl (2012); Sav (2012); Sav (2013); Tochkov et al. (2012); Wongchai et al. (2012); and Wolszczak-Derlacz (2014). However, most of them focus only on academic staff while there are few that concentrate on both type (Avkiran, 2001; Abbott & Doucouliagos, 2003; Agasisti & Salerno, 2007; Worthington & Lee, 2008; Kantabutra & Tang, 2010; Katharaki & Katharakis, 2010).

Another measure which is used to reflect labour and human capital inputs in HE production is student numbers (Athanassopoulos & Shale, 1997; Flegg et al.,2004; Cherchye & Abeele, 2005; Johnes, 2006a; Groot & Gracia-Valderrama, 2006; Johnes, 2008; Aubyn et al.,2009; Agasisti & Johnes, 2009; Agasisti & Perez-Esparrells, 2010; Wolszczak-Derlacz & Parteka, 2011; Agasisti & Pohl, 2012; Sav, 2012; Wongchai et al., 2012; Wolszczak-Derlacz, 2014). Although the time spent by students on homework and a number of classes taken are more refined measures of labour and human input (Färe, Grosskopf, & Lovell, 1994), such data are rarely available. Alternatively, to combining data on both student and staff numbers, one composite measure, namely the student–staff ratio, is constructed and used as a measure of HEIs' input (Collbert et al., 2000; Groot & Gracia-Valderrama, 2006; Worthington & Lee, 2008; Cunha & Rocha, 2012)

In addition, an attempt to capture the quality of staff input is frequently made by including staff salaries or variables reflecting the staff academic qualifications, education, or experience of the staff (Mcmillan & Datta, 1998; Cherchye & Abeele, 2005; Joumady & Ris, 2005; Groot & Gracia-Valderrama, 2006; Johnes, 2008).

In case of student quality, mean achievement scores of the student population on entry or proportion of the entry population achieving a given qualification is utilized to reflect the quality in aggregate-level studies of efficiency (Athanassopoulos & Shale, 1997; Collbert et al., 2000; Johnes, 2006a).

To reflect physical capital input in HE production, HEIs' financial data from common publications are used to construct input variables, which is a measure of the physical capital input. In numerous empirical studies, expenditures on various inputs such as library or computing facilities are used as a measure of physical capital input (for example, Beasley, 1995; Athanassopoulos & Shale, 1997; Mcmillan & Datta, 1998; Korhonen et al., 2001; Abbott & Doucouliagos, 2003; Flegg et al.,2004; Warning, 2004; Johnes, 2006a; Agasisti & Salerno, 2007; Castano & Cabanda, 2011; Johnes, 2008; Worthington & Lee, 2008; Kantabutra & Tang, 2010; Katharaki & Katharakis, 2010; Eckles, 2010; Kempkes & Pohl, 2010; Lee, 2011; Agasisti & Pohl, 2012; Cunha & Rocha, 2012; Sav, 2012; Sav, 2013).

Some studies utilize income derived for specific purposes (Athanassopoulos & Shale, 1997; Ng & Li, 2000; Johnes, 2008; Agasisti & Johnes, 2009; Kantabutra & Tang, 2010; Agasisti & Perez-Esparrells, 2010; Kempkes & Pohl, 2010; Wolszczak-Derlacz & Parteka, 2011; Cunha & Rocha, 2012; Tochkov et al., 2012; Wolszczak-Derlacz, 2014)

Moreover, the value of assets and level of investment are used in many studies to incorporate measures of physical capital, such as Abbott and Doucouliagos (2003); Johnes (2006a), Castano and Cabanda (2011); Sav (2012); Tochkov et al. (2012); and Wongchai et al. (2012). When available, the numbers of books or computers have been used as alternatives to financial data (Joumady & Ris, 2005; Johnes, 2008; Sav, 2012; Tochkov et al., 2012).

3.7.5 Explaining the Determinants of Inefficiency Using Two-Stage Data Envelopment Analysis (DEA)

By DEA technique, the relative efficiency of HEIs is determined by investigating relationship between inputs and outputs included into the DEA-model. However, according to non-parametric nature of DEA, the uncertainty (error term) is not taken into account which means that all deviation from the production frontier are from inefficiency. Furthermore, DEA assumes that HEIs have full control over inputs, suggesting that such inputs are discretionary. Obviously, this may not be the case because the deviation from production frontier may be on account of non-discretionary factors or environmental factors, beyond any managerial controls and do not directly serve as inputs into the production processes. These non-discretionary factors should be incorporated into production models so as to correctly measure HEIs efficiency (Ouellette & Vierstraete, 2004 as cited in Lee, 2011)

Bearing those non-discretionary factors in mind, determinants of HEIs' efficiency are investigated in the second stage by employing regression analysis. Ideally, in the first stage, DEA scrutinizes factors controlled by the HEIs decision-makers while the impacts of variables beyond their control, non-discretionary factors, are explained by regression analysis in the second stage. This procedure is, then, called a two-stage DEA technique.

A number of studies have handled the issue of non-discretionary factors (as shown in Table 3.3), such as McMillian and Datta (1998); Warning (2004), Cherchye and Abeele (2005); Joumady and Ris (2005); Groot and Gracia-Valderrama (2006); Kempkes and Pohl (2010); Wolszczak-Derlacz and Parteka (2011); Lee (2011); Agasisti and Pohl (2012); Sav (2013); Tochkov et al. (2012); and Wolszczak-Derlacz (2014). These studies omit the environmental variables in the initial DEA analysis, but introduce them in non-DEA sequential stages (regression analysis).

Generally, the second stage employs environmental factors along with the first stage DEA efficiency scores in a parametric formulation. Since the DEA efficiencies are less than or equal to one in value, the Tobit model comes into play for use in the majority of researches, for example, McMillian and Datta (1998); Joumady and Ris (2005); Groot and Gracia-Valderrama (2006); Kempkes and Pohl (2010); Agasisti and Pohl (2012); Sav (2013); and Tochkov et al. (2012). There are few studies employ truncates regression, such as Cherchye and Abeele (2005); Wolszczak-Derlacz and Parteka (2011); Lee (2011); and Wolszczak-Derlacz (2014).

Since, there is a problem in regressing DEA estimates on covariates (i.e. non-discretionary factors) is that the DEA efficiency estimates are, by construction, serially correlated. Simar and Wilson (2007) propose an alternative estimation and statistical inference procedure, called the DEA Double-Bootstrap, based on a bootstrap approach in which the bootstrap estimators are substituted by the estimators in the regression stage using a maximum likelihood approach to derive standard error of the estimates. This approach allows us to solve the dependency problem whilst producing valid estimates for the parameters in the second-stage regression. There exist some studies employ the DEA double bootstrap of Simar and Wilson (2007) to estimate and explain technical efficiency such as Lee (2011) and Wolszczak-Derlacz (2014).

Table 3.2 Previous Studies on the Measurement of HEIs' Efficiency with DEA Technique

Authors	Sample	Methodology	Input	Output
Beasley (1995)	chemistry and physics departments in 52 the UK. universities in 1986	Authors' developed based on DEA-model	**Teaching efficiency model** 1) General expenditure 2) Equipment expenditure 3) research income **Research efficiency model** 1) General expenditure 2) Equipment expenditure	**Teaching efficiency model** 1) Number of undergraduates 2) Number of taught postgraduates **Research efficiency model** 1) Number of research postgraduates 2) Quantity of research output (proxied by research income) 3) Index of departmental research quality
Athanassopoulos & Shale (1997)	45 HEIs in the United Kingdom during 1992–1993	1) Input-oriented approach for cost efficiency model, 2) output-oriented approach for outcome efficiency, CCR & BCC model	**Cost efficiency model** 1) General academic expenditures 2) Research income **Outcome efficiency model** 1) FTE undergraduates students 2) FTE postgraduates students 3) FTE academic staff 4) Mean A-level entry score over the last 3 years 5) Research income 6) Expenditures on library and computing	**Cost efficiency model** 1) Numbers of successful leavers 2) Number of higher degrees award 3) Weighted research rating **Outcome efficiency model** 1) Numbers of successful leavers 2) Number of higher degrees award 3) Weighted research rating

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
McMillan & Datta (1998)	45 Canadian HEIs during 1992-1993	1) Input-oriented approach, CCR & BCC model 2) 2-stages analysis through Tobit regression model	**Overall efficiency model** 1) Number of full-time faculty in the three professorial ranks 2) Number of full-time faculty eligible for MRC or NSERC grants 3) Number of full-time faculty eligible for SSHRC or Canada Council grants 4) Total expenditure less faculty salaries and benefits 5) Total operating expenditure and sponsored research expenditure	**Overall efficiency model** 1) Total FTE undergraduate student enrollment 2) FTE undergraduate enrolment in sciences 3) FTE undergraduate enrolment in other than sciences programs 4) Total FTE student enrolment in graduate programs 5) FTE graduate enrolment in master's level programs 6) FTE graduate enrolment in doctoral stream programs 7) Total sponsored research expenditures 8) Number of active SSHRC and Canada Council grants as a percentage of eligible faculty 9) Number of active MRC and NSERC grants as a percentage of eligible faculty

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Colbert et al. (2000)	24 top ranked US MBA program	Input-oriented approach, BCC model	**Teaching efficiency model** 1) Faculty to student ratio 2) Average GMAT score of students in the program 3) Number of electives offered	**Teaching efficiency model** 1) Percentage of alumni who donate money to the program 2) Student satisfaction with teaching 3) Student satisfaction with curriculum 4) Student satisfaction with placement 5) Average salary of graduates 6) Recruiter satisfaction with analytical skills 7) Recruiter satisfaction with team work skills 8) Recruiter satisfaction with graduates' global
Ng & Li (2000)	84 Chinese HEIs from during 1993 to 1995.	Output-oriented approach, BCC model	**Research efficiency model** 1) Number of researchers 2) Number of research supporting staff 3) budget funds	**Research efficiency model** 1) Number of manuscripts 2) Number of articles 3) Number of recognized research outputs 4) Number of contracts 5) Number of prizes
Avkiran (2001)	36 Australian HEIs in 1995	1) Output-oriented approach , CCR and BCC model	**Overall efficiency model** 1) FTE academic staff 2) FTE Non-academic staff	**Overall efficiency model** 1) Undergraduate enrollments 2) Postgraduate enrollments 3) Research quantum

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
		2) Identifying nature of return to scale		
			Performance on delivering education services model	**Performance on delivering education services model**
			1) FTE academic staff	1) Student retention rate (%)
			2) FTE Non-academic staff	2) Student progress rate (%)
				3) Graduate full-time employment rate (%)
			Performance on free-paying enrolments model	**Performance on free-paying enrolments model**
			1) FTE academic staff	Overseas fee-paying enrolments
			2) FTE Non-academic staff	Non-overseas fee-paying post graduate enrolments
Korhonen et al. (2001)	18 research units at the Helsinki school of economics	Output-oriented approach , BCC model	**Research efficiency model**	**Research efficiency model**
			Money	1) Articles published in international referred journals
				2) Scientific books and chapters in scientific books published by internationally well-known publishers
				3) Citations

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
				4) Publications exceeding a minimum quality standard 5) Papers in conference proceedings, domestic reports, reports in non-referred national journals, working papers and other unpublished reports 6) Conference presentations 7) Citations by other researchers 8) Invited and plenary presentations in international conferences, 9) Number of foreign co-authors in journal articles 10) Doctoral degrees produced 11) Number of doctoral students supervised 12) Memberships in editorial boards 13) Edited books and special issues of journals 14) Service as an expert 15) Scientific conferences organized 16) Memberships in program committees, etc.

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Abbott & Doucouliagos (2003)	36 Australian HEIs in 1995	Input-oriented approach , CCR and BCC model	**Overall efficiency model** 1) FTE academic staff 2) FTE non-academic staff 3) Expenditures on all non-labour inputs 4) Value of non-current assets to approximate existing capital stock	**Overall efficiency model** 1) Total number of FTE students enrollments 2) Number of post-graduate degree enrolled 3) Number of under-graduate degrees enrolled 4) Number of post-graduate degrees conferred 5) Number of under-graduate degrees Conferred 6) Research quantum
Johnes (2003)	2568 individual graduates from the UK universities department of economics in 1993.	Input-oriented approach , BCC model	**Teaching efficiency model** 1) Individual level (1) Entry score (2) Gender (3) Marital status (4) Nationality (5) Type of degree (6)Living at home (7) Type of previous school attended 2) Department level (1) Mean value of entry score (2) Number of graduates on a part-time course	**Overall efficiency model** 1) Individual level (1) Degree value (2) Degree mark 2) Department level (1) Mean value of DEGVALUE (2) Mean value of DEGMARK (3) Number of graduates (4) Number of graduates with 1st or upper second (5) Percentage of graduates with 1st or upper second

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			(3) Number of graduates who are married	
			(4) Number of graduates who are females	
			(5) Number of graduates who are from the UK	
			(6) Number of graduates who lived in the parental home	
			(7) Number of graduates who did not attend an independent school	
			(8) Percentage of graduates not on a part-time course	
			(9) Percentage of graduates who are married	
			(10) Percentage of graduates who are female	
			(11) Percentage of graduates who are from the UK	
			(12) Percentage of graduate who lived in the parental home	
			(13) Percentage of graduates who did not attend an independent school	

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Flegg et al. (2004)	45 British HEIs in the period 1980/81–1992/93	1) CCR and BCC model 2) Malmquist index 3) Identifying nature of return to scale	**Overall efficiency model** 1) Number of staff 2) Number of undergraduate students 3) Number of postgraduate students 4) Aggregate departmental expenditure	**Overall efficiency model** 1) Income from research and consultancy 2) Number of undergraduate degrees awarded 3) Number of postgraduate degrees awarded
Warning (2004)	73 Germany public HEIs during 1997-1999	1) Output-oriented approach , CCR model 2) 2-stages analysis through quartile regression model	**Publication model** 1) Expenditure on personnel 2) Other expenditure **Graduation model** 1) Expenditure on personnel 2) Other expenditure **Social sciences model** 1) Expenditure on personnel 2) Other expenditure **Sciences model** 1) Expenditure on personnel 2) Other expenditure **Total model** 1) Expenditure on personnel 2) Other expenditure	**Publication model** 1) Social science publications 2) Science publications **Graduation model** 1) Social science graduates 2) Science graduates **Social sciences model** 1) Social science publications 2) Social science graduates **Sciences model** 1) Science publications 2) Science graduates **Total model** 1) Social science publications 2) Science publications

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
				4) Social science graduates 5) Science graduates
Cherchye & Abeele (2005)	79 Research programs organized at 8 Dutch HEIs during 1996-2000	2-stages analysis through Maximum likelihood regression model	**Research efficiency model** 1) Ph.D. candidates(funding is from internal source) 2) Postdoctoral fellows, professors, associate professors and other senior staff(funding is from internal source) 3) Ph.D. candidates (funding is from scientific research funds) 4) Postdoctoral fellows, professors, associate professors and other senior staff(funding is from scientific research funds) 5) Ph.D. candidates (funding is from contract research grants) 6) Postdoctoral fellows, professors, associate professors and other senior staff(funding is from contract research grants)	**Research efficiency model** 1) Doctoral dissertations 2) Refereed articles in international journals 3) (Co-)edited) books 4) Chapters in books and proceedings

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Joumady & Ris (2005)	Graduates interviewed three years after graduation from 209 HEIs among eight European countries during 1994–95	1) Output oriented approach BCC model 2) 2-stages analysis through Tobit regression model	**Competencies model** 1) Students' entry characteristics: Entry qualification, Entry grade 2) Study provision (1): (1) Teaching characteristics (2) Equipment and stock of libraries (3) Supply of teaching material (4) Technical equipment (5) Course contents of the major (6) Practical emphasis of teaching and learning	**Competencies model** 1) Students' entry characteristics: Level of vocational competencies acquired 2) Study provision(1): Level of generic competencies acquired
			Adjustment model 1) Intensity of job search: (1)Number of job seeking modes used by graduates (2)Duration of job search 2) Study provision (2): (1) Provision of work placements (2) Importance of work experience in HEIs	**Adjustment model** 1) Intensity of job search: (1)Vertical vocational competencies match (2)Vertical generic competencies match 2) Study provision (2): Horizontal competencies match

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			Overall efficiency model 1) Students entry characteristics 2) Study provision(1) 3) Study provision (2)	**Overall efficiency model** 1) Level of vocational competencies acquired 2) Level of generic competencies acquired 3) Vertical vocational competencies match 4) Vertical vocational competencies match 5) Horizontal competencies match
Johnes (2006a)	More than 100 England HEIs in 2000/2001	-Output oriented approach, BCC model	**Overall efficiency model** 1) Number of FTE undergraduate students studying for a first degree multiplied by the average A level points for first year full-time undergraduate students 2) Number of FTE postgraduate 3) Number of full-time academic staff for teaching or teaching and research or research only purposes. 4) Total depreciation and interest 5) Total expenditure on central libraries and information services, and on central computer and computer networks excluding academic staff costs and depreciation	**Overall efficiency model** 1) Total number of first degrees awarded 2) Total number of higher degrees awarded 3) Value of the recurrent grant for research awarded by the Higher Education Funding Council for England

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			6) Expenditure on central administration and central services excluding academic staff costs and depreciation	
Johnes (2006b)	2547 individual graduates from the UK universities department of economics in 1993.	Output-oriented approach , BCC model	**Teaching efficiency model** 1) Individual level (1) Entry score (2) Gender (3) Types of previous school attended 2) Department level (1) Mean value of entry score (2) Percentage of graduates who are female (3) Percentage of graduates who did not attend an independent school	**Overall efficiency model** 1) Individual level (1) Degree value (2) Degree mark 2) Department level (1) Mean value of DEGVALUE (2) Mean value of DEGMARK (3) Percentage of graduates with 1st or upper second
Groot & Gracia-Valderrama (2006)	169 Dutch research groups in economics, econometrics and business administration in 1995, 2001	1) Input-oriented approach, CCR model 2) - stages analysis through OLS/ Tobit regression model	**Research efficiency model** 1) Number of total staff 2) Academic staff directly funded by government 3) Academic staff funded by national research councils 4) Academic staff funded by third parties	**Research efficiency model** 1) Number of dissertations(1995) 2) Number scientific publications(1995) 3) Annotations(1995) 4) Number of Professional publications (1995) 5) Number of dissertations(2001)

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			6) PhD students 7) PhD students (% of total staff) 8) Academic staff directly funded by national research council (% of total staff) 9) Academic staff funded by third parties (% of total staff)	6) Number of international academic publications(2001) 7) Number of Dutch academic publication(2001) 8) Number of Professional publication(2001)
Agasisti & Serlano(2007)	52 Italian public HEIs in 2002/2003	1)CCR and BCC model 2) Identifying nature of return to scale 3) 2- stages analysis through Tobit regression model	**Overall efficiency model** 1) Costs for academic staff 2) Costs for non-academic staff 3) Other costs (salaries) 4) Proportion of freshmen in scientific courses who obtained the best score in the secondary school (>9/10) 5) Proportion of freshmen in non-scientific courses who obtained the best score in the secondary school (>9/10)	**Overall efficiency model** 1) Number of students enrolled in scientific courses (no medicine) 2) Number of students enrolled in non-scientific courses 3) Number of students enrolled in medical courses 4) Number of students enrolled in PhD courses 5) External funds for research per researcher(×1000) 6) Drop-out rates (between first and second year of courses) in scientific courses 7) Drop-out rates (between first and second year of courses) in nonscientific courses

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
				8) Success rate in obtaining research grants by the Ministry
Castano &Cabanda (2011)	59 state universities and colleges in the Philippines during 1999-2003	1) Input-oriented approach 2) Malmquist index	**Overall efficiency model** 1) Number of faculty 2) Property, plant, and equipment 3) Total operating expenses	**Overall efficiency model** 1) Number of student enrolled 2) Number of graduates 3) Total revenue
Johnes (2008)	112 England HEIs during 1996/97-2004/05	1) CCR and BCC model 2) Malmquist index	**Overall efficiency model** 1) Number of full-time undergraduates 2) Number of postgraduate students 3) Academic staff 4) Administrative expenditures 5) Expenditures on centralized academic services	**Overall efficiency model** 1) Degrees awarded (graduate and postgraduate) 2) Research income received
Johnes & Li (2008)	109 China regular HEIs in 2003, 2004	Output-oriented approach, BCC model	**Overall efficiency model** 1) Full-time Staff to student ratio 2) Percentage of the faculty with associate professor position or higher 3) Proportion of postgraduate students 4) Research expenditure	**Overall efficiency model** 1) An index of the prestige of the HEI (reputation measure) 2) Index of total number of publications 3) Research publications per academic staff (productivity)

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			5) Capital inputs (books and area of buildings)	
Worthington & Lee(2008)	35 Australian HEIs during 1998-2003	Malmquist index	**Overall efficiency model** 1) FTE academic staff 2) FTE non-academic staff, 3) Non-labour expenditure 4) Undergraduate student load 5) Postgraduate student load	**Overall efficiency model** 1) Numbers of undergraduate completions 2) Numbers of postgraduate completions 3) Number of doctorate completions 4) Publications 5) Research grants from national competitive 6) Research grants from industry
St. Aubyn, Pina, Garcia & Pais (2009)	HEIs in the EU countries during 1998-2005	1) Output-oriented approach, CCR and BCC model 2) 2-stages analysis through Tobit regression model	**Overall efficiency model** 1) Academic staff 2) Number of students	**Overall efficiency model** 1) Number of graduates 2) THES - QS recruiter survey Ranking 3) THES - QS peer survey ranking 4) Published articles 5) Citations
Agasisti & Johnes(2009)	127 English and 57 Italian HEIs during 2001-2005	1) Output-oriented approach, CCR and BCC model 2) Malmquist index	**Overall efficiency model** 1) Total number of students 2) Total amount of financial resources/incomes 3) Number of PhD students 4) Number of academic staff	**Overall efficiency model** 1) Number of graduates (BACH and MASTER) 2) Total amount of external grants and contracts for research

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Kantabutra & Tang (2010)	22 Thai public HEIs during 2003-2006	Output-oriented approach	**Teaching efficiency model** 1) Annual operating budget 2) Number of academic staff 3) Number of non-academic staff	**Teaching efficiency model** 1) Number of graduates at the undergraduate levels 2) Number of graduates at the master degree levels 3) Employment rate
			Research efficiency model 1) Amount of internal research funds 2) Amount of external research funds 3) Number of academic staff	**Research efficiency model** 1) Number of publications in internationally refereed journals 2) Number of publications in nationally refereed journals 3) Number of doctoral graduates
Katharaki & Katharakis (2010)	20 Greece HEIs in 2004	Intput-oriented approach, CCR model	**Overall efficiency model** 1) Number of academic staff with teaching and research activity 2) Number of non-academic staff 3) Number of active registered students 4) Operating expenses other than labour inputs	**Overall efficiency model** 1) Number of undergraduates student 2) Number of undergraduate student 3) Number of post-graduate degree student. 4) Research income or else the total economic resources flowing into the HEIs as a result of the research work of teaching and research staff.

Table 3.2 (Continued)

Authors	**Sample**	**Methodology**	**Input**	**Output**
Agasisti & Perez-Esparrells (2010)	57 Italian and 46 Spanish public HEIs in 2004/2005	1) CCR and BCC model 2) Malmquist index 3) Identifying nature of return to scale	**Overall efficiency model** 1) Number of students 2) Number of PhD students 3) Number of Professors 4) Financial resources	**Overall efficiency model** 1) Number of graduates 2) Amount of external resources attracted to research activities
Eckles (2010)	93 private liberal arts colleges in the US (27 states) in 2006/2007	1) Output-oriented approach, BCC model 2) Two-stages analysis through Maximum likelihood regression model	**Teaching efficiency model** 1) Cost per undergraduate 2) Full-time faculty (%) 3) Students in the top 10% of their high school class (%) and 25th percentile of entering students' SAT scores	**Teaching efficiency model** Six-year graduation rate
Kempkes & Pohl (2010)	72 public German HEIs for the years 1998–2003	1) Output-oriented approach, BCC model 2) Two-stages analysis through Tobit regression model	**Overall efficiency model** 1) Number of technical personnel 2) Number of research personnel 3) Financial means-current expenditures 4) Total cost-third party funds	**Overall efficiency model** 1) Number of graduates 2) Number of research grants

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Wolszczak-Derlacz & Parteka (2011)	259 public HEIs in Austria, Finland, Germany, Italy, Poland, the UK and Switzerland during 2001-2005	1) Output-oriented approach, CCR model 2) Two-stage analysis based on bootstrap truncated regression	**Overall efficiency model** 1) Total academic staff 2) Total number of students 3) Total revenues	**Overall efficiency model** 1) Number of graduations 2) Number of scientific publications
Lee (2011)	37 Australian HEIs during 2007-2009.	1) Input-oriented approach, BCC model 2) Two-stage analysis based on bootstrap truncated regression	**Research efficiency model** 1) Full-time equivalent (FTE) staff which comprise of aggregation of 'research only' and 'teaching and research' 2) Expenditure on 'buildings, library and other properties, plant and equipment' (in dollars).	**Research efficiency model** 1) National competitive grants 2) Industry grants 3) Other public sector grants 4) Research publication 5) Number of 'Master's' and 'Doctorate' students by research.
Agasisti & Pohl (2012)	Italian and German public universities during 2001-2007	1) Output-oriented approach, CCR, BBC model 2) Malmquist index 3) Two-stage analysis through Tobit regression model	**Overall efficiency model** 1) Number of students enrolled 2) Number of professors 3) Current expenditures	**Overall efficiency model** 1) Number of university degrees awarded 2) External research grants and contracts

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
Cunha & Rocha (2012)	48 Portugal HEIs in 2998	Input-oriented approach, CCR and BBC model	**Teaching efficiency model** 1) Total funding per student 2) Total expenditure per student 3) Academic staff per student	**Teaching efficiency model** 1) Total graduate students 2) Total PhD. Degree awarded 3) Total numbers of Course
Sav (2012)	133 U.S. research and doctoral HEIs during 2005-2009	1) Output-oriented approach, CCR and BBC model 2) Malmquist index 3) Identifying of return to scale	**Overall efficiency model** 1) Number of teaching and Research Faculties 2) Number of administrative Faculties 3) Capital Equipment, Dollars 4) Academic Support, Dollars 5) Auxiliary Capital, Dollars|	**Overall efficiency model** 1) Undergraduate Education, Credit Hours 2) Graduate Education, Credit Hours 3) Research, Dollars
Sav (2013)	331 U.S. publicly HEIs over four academic years, 2005-2009	1) Output-oriented approach, CCR and BBC model 2) Two-stage analysis through Tobit Regression	**Overall efficiency model** 1) The total 12 month unduplicated undergraduate enrollment 2) Number of graduate enrollment 3) Total faculty employment 4) Expenditures per student 5) The annual expenditure on academic support expressed as a percentage of total university expenditures	**Overall efficiency model** 1) Total annual undergraduate credit hours 2) Total annual graduate credit hours 3) The HEIs receipt of research grants and contracts

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			6) Value of equipment 7) Value of buildings 8) Annual total university expenditure	
Tochkov et al. (2012)	46 of the 50 accredited HEIs in Bulgaria in 2009	1) Input-oriented approach, BBC model 2) Two-stage analysis through censored Regression	**Overall efficiency model** 1) Number of academic staffs 2) Size of area used for teaching and research 3) Number of library items 4) Amount of research funds **Teaching efficiency model** 1) Number of academic staffs 2) Size of area used for teaching and research 3) Number of library items **Research efficiency model** 1) Number of academic staffs 2) Size of area used for teaching and research 3) Amount of research funds	**Overall efficiency model** 1) Number of domestic students 2) Number of foreign students 3) Mean salary after graduation 4) Unemployment rate 5) Number of peer-reviewed publications 6) A citation index-Citation index **Teaching efficiency model** 1) Number of all students 2) Number of domestic students 3) Number of foreign students 4) Mean salary after graduation 5) unemployment rate **Research efficiency model** 1) Number of peer-reviewed publications 2) A citation index-Citation index

Table 3.2 (Continued)

Authors	Sample	Methodology	Input	Output
			Cost efficiency model 1) Average annual academic salary 2) Non-salary operating costs per square meter of floor area	**Cost efficiency Model** 1) Number of all students 2) Mean salary after graduation 3) Unemployment rate 4) Number of peer-reviewed publications 5) A citation index-Citation index 6) Academic salary 7) Operating costs
Wongchai et al.(2012)	77 national universities in 2011 in Thailand	DEA meta-frontier	**Overall efficiency model** 1) Number of current teachers 2) Number of current students 3) Number of current staffs 4) Number of educational aids' depreciation	**Overall efficiency model** 1) Number of publications 2) Number of graduated students 3) Number of researches and developments 4) Number of research funds
Wolszczak-Derlacz (2014)	500 HEIs in 11 countries (10 European countries and the US)	1) Output-oriented approach, CCR model 2) Malmquist index 3) Two-stage analysis based on bootstrap truncated regression	**Overall efficiency model** 1) Total revenue 2) Total number of academic staff 3) Total number of administrative staff 4) Total number of students	**Overall efficiency model** 1) Total number of publication 2) Total number of scientific articles 3) Total number of graduates

Table 3.3 Previous Studies on the Measurement of HEIs' Efficiency with 2-stages DEA Technique

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
McMillan & Datta (1998)	To explain the efficiency score obtained from DEA	45 Canadian HEIs during 1992-1993	Tobit regression	1) Number of student enrolment in universities within 200 Km. 2) Number of undergraduate FTE enrolment per undergraduate degree awarded 3) Number of student enrolment divided by total student enrolment 4) Proportion of third and fourth year classes with less than 26 students 5) Proportion of full-time faculty eligible for MRC and/or NSERC grants 6) Herfindahl index 7) Percentage change in total enrolment, 1990-91 to 1992-93 8) Percentage change in total revenue, 1989-90 to 1992-93 9) Total full-time equivalent student enrolment
Warning (2004)	To investigate the impact of strategic variables on HEIs' performance	73 Germany public HEIs during 1997-1999	Quartile regression	1) Publication-graduate ratio for social sciences 2) Publication-graduate ratio for natural sciences 3) Proportion of social publications in the total number of publications

Table 3.3 (Continued)

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
				4) Amount of research grants 5) Dummy variable for the presence of medicine faculty 6) Age of the university 7) Number of students 8) Number of residents in town in which the university is located 9) Dummy variable for location in former West Germany 10) Herfindhal-index of students
Cherchye & Abeele (2005)	To investigate the impact of program sizes and external funding on the observed performance of research program	79 Research programs organized at 8 Dutch HEIs during 1996-2000	Truncated regression	1) Program sizes 2) External funds 3) Program launching year 4) Specialization type
Joumady & Ris (2005)	To reveal efficiency' determinants	a young graduates interviewed three years after graduation from 209 HEIs among eight European	Tobit regression	1) Graduates characteristics (1) Percentage of men (2)Age (3) Percentage of graduates having father with higher education

Table 3.3 (Continued)

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
		countries during 1994–1995		(4) Percentage of graduates having spent time aboard (5) Percentage of graduates having spent time on internship 2) Labour market characteristics (1)Percentage higher educated workers on the labour market (2)Unemployment rate (3)Employment protection index (4)Share of temporary employed worker
Groot & Gracia-Valderrama (2006)	To explain differences in research quality and productivity	169 Dutch research groups in economics, econometrics and business administration in 1995, 2001	OLS regression/Tobit regression	1) Total FTE staff 2) Percentage of PhD students 3) Percentage of national funding 4) Percentage of third party funding 5) Dummy variable for Economics 6) Dummy variable for Business Administration
Kempkes & Pohl(2010)	To detect the impact of faculty composition on efficiency	72 public German HEIs for the years 1998–2003	Tobit regression	1) GDP per capita (year) 2) Dummy variable for Medical faculty 3) Dummy variable for Engineering faculty

Table 3.3 (Continued)

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
Wolszczak-Derlacz & Parteka (2011)	To reveal external determinant of efficiency	259 public HEIs in Austria, Finland, Germany, Italy, Poland, UK and Switzerland during 2001-2005	Truncated regression	1) Real GDP per capita in euro PPS of the region where the university is located 2) Number of different faculties 3) Dummy variable for medical or pharmacy faculty 4) Year of foundation 5) Share of core funding revenues in total revenues 6) Share of women in the academic staff
Lee (2011)	To analyze drivers of efficiency	37 Australian HEIs during 2007-2009.	Truncated regression	1) Actual student load factor 2) Dummy variable for location of university (city based or non-city based) 3) Proportion of Associate Professors and Professors to total academic staff 4) Institutional Grants Scheme
Agasisti & Pohl (2012)	To investigate the effect of economic circumstance on HEIs' efficiency	Italian and German public universities during 2001-2007	Tobit regression	1) Dummy variable for Medical 2) Dummy variable for locating in the North Italy or West Germany 3) GDP per capita of the region where the university is located

Table 3.3 (Continued)

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
				4) Unemployment rate 5) Human resources employed in Science and Technology
Sav (2013)	To explore how the alternative financing resource dependencies affects HEIs' performance	331 the U.S. public HEIs over four academic years, 2005-2009	Tobit regression	1) Tuition charges 2) Government funding 3) Proportion of university revenue generates 4) Time variable (Dummy)
Tochkov et al.(2012)	To explore the relationship between public funding and efficiency level of HEIs	46 of the 50 accredited HEIs in Bulgaria in 2009	Maximum likelihood regression	1) Dummy variable for Source of funding (1 for financed from the government budget, and zero for relying on private funding) 2) Ratio of HEIs' students to the total number of students across all institutions 3) Number of fields of study 4) Share of science-related fields of study (SCI) 5) Number of accredited doctoral degree programs 6) Total HEIs' revenue per student 7) Government subsidy per student

Table 3.3 (Continued)

Authors	Objective	Sample	Regression Model	Independent Variable (Dependent variable → Efficiency score)
Wolszczak-Derlacz (2014)	To explore the determinants of HEIs' inefficiency	500 HEIs in 11 countries (10 European countries and the US)	Truncated regression	1) Real GDP per capita in euro PPS of the region where the university is located 2) Number of different faculties 3) Dummy variable for medical or pharmacy faculty 4) Dummy variable for technical university 5) Year of foundation 6) Share of core funding revenues in total revenues/ Share of tuition fee in total revenues

Notes: Studies are Presented in Chronological Order

3.8 Previous Studies on the Influences of Public Funding on Higher Education Institutions Performance

Public funding for HEIs can obviously influence HEIs management which ultimately contributes to HEIs' efficiency, both in term of quality and quantity. Jongbloed (2004) argued that public funding for HEIs is more than merely a mechanism to allocate financial resources as it is part of the set of tool and other governance instruments that enforce common goals set for HE such as access and efficiency; establish incentive for certain behaviour such as competitive research grant; and attempt to maximize the desired output with limited resources. Therefore, public funding for HEIs is not an end in itself. Rather, it is a mean to an end, it is used as an instrument of public authorities to affect the behaviour of an agent or an organization.

Moreover, the type of funding mechanism adopted has different effects in various facets of the HEIs operation such as equity of student access; autonomy of institutes, influences from funding sources; competition among institutes; stability of institutes; responsiveness to students and labour market demands; quality of education; and the fiscal burden of the government, tax payers and household (Cheung, 2003; Salmi & Hauptman, 2006). Additionally, changes in funding system, that is, shift in source of financial resources, or in the form of resources allocation are likely to have a major impact on the behaviour of HIEs as well as their internal process of resources allocation (Liefner, 2003). However, under any allocation systems, government and HEIs must be accountable for their actions and their spending, meaning that resource allocation and accountability are intertwined. Without accountability, HEIs may engage in too many researches and scholarships, fail to respond to student needs and become inefficient. Furthermore, both accountability and resource allocation models need to support HEIs governance and management (Nkrumah-Young & Powell, 2008).

Presently, there are few empirical studies on the relationship between public funding system for HEIs and reactions of HEIs to those funding systems which eventually affect on their performance. Those are Garcia-Penalosa and Walde (2000);

Liefner (2003); Caballero, Galache, Gómez, Molina, and Torrico (2004); Amaral et al. (2007); Bevc and Uršič (2008); Tajnikar and Debevec (2008), and Frølich et al. (2010). Garcia-Penalosa and Walde (2000) compare the efficiency and equity effects of three HE financing systems: the traditional tax-subsidy system, where education subsidies are financed from general taxation; loan schemes; and a graduate tax. The results reveal that efficiency and equity targets cannot be simultaneously achieved by the traditional tax-subsidy system, and that both loan schemes and a graduate tax fare better. When education outcomes are uncertain, the graduate tax is preferred to a pure loan scheme because of the greater insurance provided by the former and because it tends to be preferable to an income contingent loan system.

Liefner (2003) analyses how various forms of funding and resource allocation affect universities at the macro-level and individual behaviour at the micro-level. A hypothesis to this problem is that performance-based funding tends to bring about positive changes but is also a factor in unintended side effects. As resource allocation forms influence the behaviour of academics and managers in HEIs, particularly their levels of activity as well as the kinds of activities they engage in and their ways of dealing with risks. The study results partly confirm this hypothesis. It can be shown that changes in resource allocation have an impact on the level and type of activity academics concentrated on but not on the long-term success of universities

By using DEA and multiple criteria decision making (MCDM), Caballero et al. (2004) proposes a methodology to serve as a guiding mechanism for the allocation and management HEIs financial resources taking efficiency as its objective. Specifically, an aid model is provided for decision making so that the planning of staff policy within a HEI guarantees an equal treatment of all the teaching and research units, greater transparency in the allocation of financial resources, as well as a rational monitoring of the allocations made and their effects on the university efficiency levels. The results show that the allocation of budgetary funds for hiring teaching staff among departments at the University of Malaga in Spain improved the average technical efficiency with respect to teaching.

Amaral et al. (2007) analyses the Portuguese HE funding policy and its consequences over the institutions and the system as a whole. The main objective of this study is to understand how the different allocation mechanisms have affected institutional strategies and the behavior of academics as well as what are eventual non-intended effects of the funding mechanisms. The study shows that the introduction of a funding formula for the HEIs teaching activity is seen in general as positive and adequate for a period of expansion that is promoted by linking funding to student enrolments. At present the expansion period has come to an end and there is tendency to pay increasing attention to the quality and efficiency of institutions. Therefore the formula has been changed to include elements related to quality. However the new formula is not yet stable and it is too early to analyze its effects. Moreover, the two major problems of the funding systems of HE are, on one hand, the large dependence of the funding for teaching on student enrolments, which contributed to some unintended effects and did not promote academic efficiency while, on the other hand, the separation of the funding systems for teaching and research creates a gap between these two activities.

Bevc and Uršič (2008) analyses the relationship between funding, equity and efficiency of HE, considering a funding system as the basic issue and the research results show that the three issues are highly inter-related. Arrangements regarding both parts of the funding system can have a great impact on cost-sharing among different bearers, accessibility to HE and other dimensions related to equity issues, as well as on both internal and external efficiencies. However, measuring the relationships between funding, equity and efficiency of HE is not an easy task for several reasons – among all, the following are of special importance: the existence of direct and indirect links; the existence of impacts in both directions (mutual connections); and the complexity of the HE funding system including two complementary sub-systems (funding of institutions and state financial support to students), both of which influence equity and efficiency. In addition, the mechanism of funding HEIs from public sources is based on funding institutions' outputs. Tuition fees are considered an efficient and equitable form of funding educational institutions, but only in case that they are combined with a relevant system of state support economically to underprivileged students. In contrast, direct state financial support to students with the most positive effects on internal efficiency and equity involves a combination of student loans and fellowships/grants.

Tajnikar and Debevec (2008) aim to tackle the issue of the HE funding system in Slovenia. Analysis is conducted by using DEA tested whether members of the University of Ljubljana are classified into groups according to their relative technical efficiency and SGF values being aligned with the relative differences between them. The study results confirm the heterogeneity of the study groups, the inappropriate formation of one group, inaccurate classification of institutions and that the SGF values of different study groups are too high in relative to the base group. This means that inefficient departments within the University of Ljubljana in Slovenia received disproportionately more funds than efficient ones.

In order to discuss how funding systems influence HEIs and their strategies and core tasks, Frølich et al. (2010) takes the results of a comparative study between Denmark, Norway and Portugal as a point of departure in which the paper identifies and analyses the main features of these state funding systems, their strengths and weaknesses, and their impact on academia. The findings reveal that mixed funding models have been implemented in all three countries. However, funding systems and their impacts do not come in neat packages. The systems demonstrate a mixed pattern of strengths and weaknesses. The impacts of the funding systems converge, although different mechanisms are employed show no clear cut differences in the perceived strengths, weaknesses and impacts of the two main types of funding systems, input-based funding and output-based funding, presented and discussed in the paper.

In sum, the common objective of those studies is to understand how the difference in public funding systems for HEIs affects their strategy and, then, behavior of HEIs' staff which eventually results in their performance. The majority of the results indicates that the difference in public funding systems for HEIs affects their performance. Moreover, there are many perceived positive effects of changing in public funding on HEIs such as 1) increase autonomy, performance, and competition; 2) increase effectiveness, efficiency, and transparency; 3) enhance internationalization; 4) improve quality, innovative curricula; 5) improve cooperation with other institutions; 6) focus on student needs and customer orientation; and 7) high budget flexibility and incentive for development and change. Meanwhile, a number of perceived negative effects include 1) loss of variety in research and teaching; 2) elimination of studies presently not in demand or expensive studies; 3) neglect of basic research and basic development; 4) negative steering effects through (dysfunctional) indicators in formulas; and lower quality of research and teaching (Liefner, 2003).

Although, the change in resource allocation influences the level and type of academic activity, it does not guarantee the impact on the HEIs long run success. For example, the studies of Garcia-Penalosa and Walde, (2000), Bevc and Uršič (2008), and Frølich et al. (2010) show that the countries may not be able to achieve their objective and intended effects of implementing new funding system, particularly in improving HEIs' efficiency. As a result, the significant implication from those studies as mentioned above is that the appropriate funding system may be one of several factors that improve HEIs' efficiency.

CHAPTER 4

METHODOLOGY

Methodology applied in this study is divided into two parts. The first part, section 4.1, relates to the measurement of public HEIs' technical efficiency whereas in the second part, section 4.2, the effects of public funding on HEIs' technical efficiency is examined.

4.1 Measurement of Public Higher Education Institutions Technical Efficiency

As mentioned in section 3.1, the institutional performance in HE context consists of two dimensions: efficiency and effectiveness. The effectiveness which illustrates the success of using resources to achieve the objectives pursued is harder to accomplish than efficiency because it is influenced by other external factors beyond the control of HEIs. Therefore, the performance of HEIs, in this study, is principally focused on efficiency dimension.

According to Farrell (1957), efficiency can be demonstrated in terms of technical, allocative, and total economic efficiency, a product of technical and allocative efficiency. However, the measurement of allocative efficiency requires most notably information on input and output prices because it reflects the relationship between the optimal combination of inputs taking into account costs of production and the given level of output, or the relationship between the optimal combination of outputs taking into account revenues of production and the given level of input. Yet, in HE production, the knowledge of input and output prices are often blurred, allocative efficiency is, then, not suitable to apply in HE context. Accordingly, the measurement of HEIs' efficiency in this study is mainly focused on technical efficiency.

As indicated in 3.3, there is a wide range of different techniques dedicated to estimate a production frontier function, the two most popular techniques are: Stochastic Frontier Analysis (SFA); Data envelopment Analysis (DEA).

However, public HEIs encompass some characteristics making the measurement of their technical efficiency become difficult than any organizations in private sector to use the regular methods such as profit maximization or cost minimization to determine the optimal combination of inputs and outputs. Those characteristics are: 1) operation in public HEIs are typically complex with a variety of inputs and outputs taking part in the production process, and with a diverse objective; 2) knowledge of input and output prices within public HEIs production process is often unknown; 3) some outputs of public HEIs can't be measured because of their nature such as social externalities of HE; and 4) imposing a functional form on the production process is not an easy task in HE context.

According to the characteristics of public HEIs, as earlier mentioned, together with the features and advantages of DEA techniques, as mentioned in Table 3.1, there are six reasons why this study adopts DEA method for measuring technical efficiency of public HEIs.

Firstly, due to the nature of HE production process which mutually employs multiple inputs to produce multiple outputs along with the absence of input and output prices, DEA technique which can handle with the efficiency measurement of multiple inputs and outputs, is then an attractive choices.

Secondly, within HE sector where the production process is largely unknown, parametric estimation techniques, like a SFA, which requires imposing additional assumptions about the technology might lead to biased and inconsistent estimators because the technology is incorrectly specified. DEA technique which requires no predefined structure or specific functional form to be imposed on the data in identifying and determining the efficient frontier is more preferable than SFA technique.

Thirdly, DEA technique can underline the areas of improvement for each single HEI such as either the input has been over utilized, or output has been under produced by the HEIs, as a result, they could improve on efficiency. Moreover, the efficient frontier can be used to set targets for inefficient HEIs and these targets could lie anywhere along the efficient frontier. Often it is useful to set an output target reflecting the output which would be needed to bring a producer up to the technical efficient frontier if inputs remained unchanged. Alternatively an input target could be imposed under the assumption that output remains unchanged. Any mix of these approaches is possible.

Fourthly, besides producing a ranking of sampled institutions based on technical efficiency score, DEA technique can also identify HEIs peer or benchmark which may be of great value for administrators and public policy makers to learn from them for improving HEIs' performance. In contrast, if the assessment scores from internal and external quality assurance by OHEC and ONESQA (as reported in HEIs' self-assessment report) are applied to measure the performance of HEIs, it might be complicated to use these scores for identifying the HEIs ranking and the peer group. This is because, in Thai HE system, each HEI can freely classify itself into 4 groups: 1) research and postgraduate universities, 2) specialized including science and technology and comprehensive universities, 3) four-year universities and liberal arts colleges, and 4) community colleges, such that the standard criteria of some key performance indicators(KPIs) in each group is different. Moreover, scoring for each KPIs arising from the transformation of related actual data to score by using standard criteria causes the reduction in HEIs' difference which is essential for ranking of their performance.

Fifthly, in order to calculate aggregate inputs and output to obtain the measure of technical efficiency, information about the prices of all inputs and outputs is necessitated as the weights representing the relative importance of each input and output. A full set of prices may exist in case of private DUMs. Yet, in case of public sector production, like public HEIs, prices typically do not exist or do not reflect social values; hence, DEA method is suitable for analysing efficiency of public HEIs. It allows each HEI to select its own weights on inputs and outputs rather than requiring a judgment on their relative importance that allows inputs and outputs to be separately aggregated and efficiency scores to be analysed. Such flexibility, therefore, allows HEIs to differ in terms of circumstances and objectives. On the contrary, the assessment by OHEC and ONESQA requires predetermined weight assigned to each KPI on the relative significance, the score from this assessment is not applicable to reflect HEIs performance which is in different conditions and has different objectives.

Finally, DEA technique does not need standardization and this allows researchers to choose any kind of input and output of managerial interest regardless of the different measurement units.

4.1.1 Measurement of Technical Efficiency Using Data Envelopment Analysis (DEA)

As mentioned in section 3.4, DEA is a non-stochastic, non-statistical, and non-parametric approach for evaluating relative efficiency of homogeneous DMU by comparing it with a group of DMUs that transforms the same group of measurable inputs into the same types of measurable outputs. The objective of DEA is to construct a non-parametric piece-wise production frontier (or efficient frontier) which envelopes all sample observation by using linear programming techniques. This frontier is determined by units being on it, that is efficient DMUs. On the other hand, units not being on that frontier can be considered as inefficient DMUs and their technical efficiency score is separately calculated, relative to the frontier. The best practice units, then, can be extracted from the group of DMUs by comparing their inputs and outputs to other DMUs under consideration.

4.1.1.1 Input and Output Orientation of Data Envelopment Analysis (DEA)

With regard to the definition of production set, there are two approaches in applying DEA model: input-oriented approach and output-oriented approach, as stated in section 3.4. The aim of an input-oriented approach is to proportionally reduce the required inputs so far as possible while the level of outputs is held constant. On the other hand, an outputs approach endeavours to proportionally expand outputs as much as possible while an inputs level is given. Generally, the difference between these approaches depends on the extent to which inputs or outputs are controllable. Both approaches lead to the same efficiency score under the CRS assumption, but not under the VRS assumption. However, these options estimate similar production frontier and identify the same set of efficient DMUs while the difference in efficiency score only occurs with inefficient DMUs (Coelli, 1996).

In HE sector, resources allocated to public HEIs are more or less fixed, and these HEIs cannot easily adjust their inputs such as academic or non-academic staff, capital, etc. without government approval. Moreover, they are usually asked to produce outputs level as much as possible. Consequently the output-oriented approach is considered to be more appropriate for constructing a DEA model. In this orientation approach efficiency is interpreted as potential increase in outputs for a given level of inputs. The selected approach is similar to the majority of empirical studies that utilize output-oriented approach of DEA to measure HEIs' technical efficiency in HE context, for example Ng and Li (2000), Avkiran (2001), Korhonen et al. (2001), Warning (2004), Joumady and Ris (2005), Johnes (2006a, b), Johnes and Li (2008), Aubyn et al. (2009), Kempkes and Pohl (2010), Eckles (2010), Kantabutra and Tang (2010), Wolszczak-Derlacz and Partera (2011), Agasisti and Pohl (2012), Sav (2012), Sav (2013), and Wolszczak-Derlacz (2014).

4.1.1.2 Data Envelopment Analysis Model

Another analysis optional in DEA is a choice between CRS and VRS assumption. CRS assumes that there is no significant relationship between the scale of operations and efficiency. That is, large HEIs are just as efficient as small ones in converting inputs to outputs. On the other hand, VRS means a rise in inputs is expected to result in a disproportionate rise in outputs. VRS is preferred when a significant correlation between DMU size and efficiency can be demonstrated in a large sample (Johnes & Johnes, 1995). Regarding CRS and VRS assumption, two DEA models are as follow:

Output-oriented DEA-CCR Model:

$$\begin{aligned}
&\text{Maximize} \quad \emptyset_t + \varepsilon \textstyle\sum_{r=1}^{m} s_r + \varepsilon \sum_{r=1}^{n} s_i \\
&\text{Subject to} \quad \phi_t y_{rt} - \textstyle\sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0;\ \ r = 1, \dots, m \\
&\qquad x_{it} - \textstyle\sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0;\ \ i = 1, \dots, n \qquad (4.1) \\
&\qquad \lambda j,\ sr,\ si \geq 0;\ \ \forall j = 1, \dots, N
\end{aligned}$$

Output-oriented DEA-BCC Model:

$$\begin{aligned}
&\text{Maximize} \quad \emptyset_t + \varepsilon \textstyle\sum_{r=1}^{m} s_r + \varepsilon \sum_{r=1}^{n} s_i \\
&\text{Subject to} \quad \phi_t y_{rt} - \textstyle\sum_{j=1}^{N} \lambda_j y_{rj} + s_r = 0;\ \ r = 1, \dots, m \\
&\qquad x_{it} - \textstyle\sum_{j=1}^{N} \lambda_j x_{ij} - s_i = 0;\ \ i = 1, \dots, n \qquad (4.2) \\
&\qquad \textstyle\sum_{j=1}^{N} \lambda_j = 1 \\
&\qquad \lambda j,\ sr,\ si \geq 0;\ \ \forall j = 1, \dots, N
\end{aligned}$$

where x_{ij} and y_{rj} denote the amount of input i (i=1,…,n) and amount of output r (r =1,…,m) used by HEIs j (j=1,…, t,…,N). Besides, s_r and s_i denote an output and input slacks, respectively. The solution of the above linear programming problem is a set of efficiency scores where the technical efficiency of HEIs t is computed by the ratio 1/ϕt.

Thus, DMUt is efficiency if the efficiency score TE_t = θt = 1 (equivalently, TE_t = 1/ϕt = 1) and the slack sr and si = 0, ∀r =1, …, m and ∀i = 1, …, n. These efficiency scores are based on the definition of efficiency which involves two types of DMUs: observed and virtual units. The virtual units have an efficiency score equals to 1 which is considered as efficient units while the remaining units have a score less than 1, representing the distance of these units from the efficient frontier.

However, in the real world, the optimal scale under CRS assumption is often precluded by a variety of circumstances such as different types of market power, constraints on finances, externalities, imperfect competition, etc. (Coelli et al., 2005). Moreover, the CRS assumption yields misleading measures of technical efficiency in the sense that technical efficiency scores reported under that set of constraints are biased by scale efficiencies (Avkiran, 2001). To comply with reality, this study, then, deploys the Output-oriented DEA-BCC Model (4.2) to obtain technical efficiency of public HEIs, as mentioned in the previous section.

4.1.2 Measurement of Scale Efficiency

According to Coelli et al. (2005), under VRS assumption, an evaluated DMU may be too small in its scale of operation which might fall within the increasing returns to scale (IRS) part of the production frontier. Similarly, an evaluated DMU may be too large and it may operate within the decreasing returns to scale (DRS) part of the production frontier. In both cases, efficiency of the DMUs might be improved by changing their scale of operations, i.e., to keep the same input mix but change the size of operations. This implies that scale size of production affects the productivity of a DMU.

Some important questions arise regarding the scale size at which a DMU operates. For example, is there a scale size that would be optimal in some sense for the DMU? How far the scale size of a unit is away from optimal? These questions are captured in the concepts of scale efficiency.

Scale efficiency refers to the amount by which productivity can be increased by moving to the optimal scale size. The optimal scale size to operate at is where CRS holds. This optimal scale size is defined as Most Productive Scale Size (MPSS), termed by Banker (1984), with reference to a specific mix of inputs and outputs. In a single input/single-output framework, MPSS is offered by the unit(s) offering maximum average product or output-input ratio.

To measure the scale efficiency for each HEI, both the Output-oriented DEA-CCR Model and Output-oriented DEA-BCC Model must be estimated. The technical efficiency score obtained from the CCR model (TECCR) is then decomposed into two elements: pure technical efficiency obtained from the BCC model (TEBCC) and scale efficiency (SE).

$$TE_{CCR} = TE_{BCC} \times SE \tag{4.3}$$

If there are differences between the estimated technical efficiency score obtained from the DEA-CCR model compared with the estimated technical efficiency score obtained from the DEA-BCC model, it can be concluded that the HEIs has scale inefficiency.

As a result, the scale efficiency (SE) is defined by equation below:

$$SE = \frac{TE_{CCR}}{TE_{BCC}} \tag{4.4}$$

If there are differences between the computed technical efficiency score obtained from the DEA-CCR model compared with the estimated technical efficiency score obtained from the DEA-BCC model, it can be concluded that the HEIs has scale inefficiency. Moreover, as technical efficiency (CRS technical efficiency) of a DMU can never exceed its pure technical efficiency (VRS technical efficiency) in either orientation, thus, from the definition of scale efficiency above, scale efficiency can never be greater than 1.

Although, this decomposing discovers the existing scale of production and scale efficiency in each DMU, its usefulness is limited as it only demonstrates the existence of scale inefficiency without suggestion of the nature of return to scale (RTS) which is the valuable information for managerial decision making.

4.1.3 Identification of the Nature of Return to Scale (RTS)

In the DEA literature, there are three basic methods to investigate DMUs' RTS nature (Seiford & Zhu, 1999): 1) CCR-RTS method, developed by Banker (1984), 2) BCC-RTS method, developed by Banker et al. (1984), and 3) scale efficiency index method, developed by Färe and Grosskopf (1985). These three RTS methods, in fact, are equivalent but different presentations. However, it has been noted that the CCR and BCC RTS methods may fail when DEA models have alternate optima, since the original CCR and BCC RTS methods assume unique optimal solutions to the DEA formulations. In contrast to these two methods, the scale efficiency index method does not require information on the primal and dual variables. Particularly, it is robust even when multiple optima exist since it may be impossible or at least unreasonable to generate all possible multiple optima in many real world applications.

Therefore, this study employs the scale efficiency index method to identify DMUs' RTS nature. This method requires three efficiency measures, respectively, in relation to three technological return-to-scale specifications: CRS, VRS, and NIRS (Non-Increasing-Return to Scale). To obtain technical efficiency score under CRS and VRS assumption, model (1) and (2) are solved, respectively. In addition, the following model (5) is solved to achieve the technical efficiency score under NIRS assumption, as follows.

Output-oriented DEA-NIRS Model:

$$Maximize\ \emptyset_t + \varepsilon \sum_{r=1}^{m} s_r + \varepsilon \sum_{i=1}^{n} s_i$$

$$Subject\ to\ \emptyset_t Y_{rt} - \sum_{j=1}^{N} \lambda_j Y_{rj} \le 0; r = 1, \ldots, m$$

$$X_{it} - \sum_{j=1}^{N} \lambda_j X_{ij} \ge 0; i = 1, \ldots, n \qquad (4.5)$$

$$\sum_{j=1}^{N} \lambda_j \le 1$$

$$\lambda_j, s_r, s_{i\ge} \ge 0;\ \forall j = 1, \ldots, N$$

In model (4.5), the convexity constraint $\sum_{j=1}^{N} \lambda_j \le 1$ is used to substitute $\sum_{j=1}^{N} \lambda_j = 1$.

The technical efficiency score obtained from model (4.5) is then compared with the technical efficiency score in the DEA-CCR DEA-model (4.1) and the DEA-BCC model (4.2), according to the following conditions

1) If CRS, VRS, and NIRS models yield exactly the same efficiency measure, then the unit lies or is projected on a boundary region exhibiting local CRS.

2) If CRS and NIRS efficiency measures are both equal and lower than the VRS efficiency measure, then the unit lies or is projected on an IRS region of the boundary.

3) If VRS and NIRS efficiency measures are both equal and higher than the CRS efficiency measure, then the unit lies or is projected on a DRS region of the boundary.

4.1.4 Inputs and Outputs Specification

Since the core missions of a HEI are teaching and research, particular attention in this study has been paid on teaching and research missions. Moreover, separate assessment of teaching and research efficiencies is expected to provide more insight in the Thai HE system such as a study on the relationship between teaching and research performance, and the discrimination of research-efficient and teaching-efficient HEIs. In order to capture HEIs' efficiency in these different aspects, two efficiency models are created: teaching efficiency model and research efficiency model. Therefore, the specification of inputs-outputs employed in DEA model will be explained regarding the type of efficiency model as follows.

4.1.4.1 Teaching Efficiency Model

1) Teaching Inputs. To produce and disseminate knowledge through teaching activity, HEIs employ human-capital (e.g. student numbers, student's characteristics, staff numbers, time invested by staff and students, and qualification of academic staff) and physical-capital (e.g. land, building, and laboratory equipment) to educate enrolled students for the purpose to produce graduates with a certain level of quality.

One of teaching inputs included into HE production process as a measures of human-capital is the number of Full Time Equivalent students (FTEs) (for example, see Flegg et al. (2004); Cherchye and Abeele (2005); Johnes (2006a); Groot and Gracia-Valderrama (2006); Johnes (2008); Aubyn et al. (2009); Agasisti and Johnes (2009); Agasisti and Perez-Esparrells (2010); Wolszczak-Derlacz and Partera (2011); Agasisti and Pohl (2012); Sav (2013); Wongchai et al. (2012); and

Wolszczak-Derlacz (2014). Therefore, in this study, the number of FTEs (FTEST) is utilized as a measure of human-capital input. Moreover, in order to take quality of students enrolled in HEIs into account, some previous studies used entrance examination scores to reflect the quality of students (see Athanassopoulos & Shale, 1997; Johnes, 2006a). Unfortunately, since the unavailable of the data reflecting the quality of student enrolled in Thai HEIs, this study focuses only on quantitative dimension of this input.

Another common measure used to represent human-capital input is the quantity of academic staff (for example, see Avkiran, 2001; Abbott & Doucouliagos, 2003; Johnes, 2006a; Johns, 2008; Johnes & Li, 2008; Worthington & lee, 2008; Aubyn et al., 2009; Agasisti & Johnes, 2009; Kantabutra & Tang, 2010; Katharaki & Katharakis, 2010; Wolszczak-Derlacz & Partera, 2011; Lee,2011; Cunha & Rocha, 2012; and Sav, 2012). This category of input includes all personnel whose primary assignment is instruction or research (covering, namely, those holding an academic position). Although the number of FTEs academic staff should be considered as additional measures of teaching input in HE production process, due to the unavailable of FTEs data in Thai HE system, the total number of academic staff is utilized instead of the number of FTEs academic staff. Moreover, to reflect both quantitative and qualitative aspects of academic staff in one variable, the number of academic staff holding assistance professor or higher (ACSTWAP) is employed in this study. However, the roles of non-academic staff are also important in administering students and academic staffs, and facilitating the research and teaching process in general, therefore, the number of non-academic staff (NACST) is also taken as the further measures of teaching input in production process.

In previous studies, to reflect physical-capital input in HE production, expenditures on various inputs such as library or computing facilities (for example, see Korhonen et al.,2001; Abbott & Doucouliagos, 2003; Flegg et al.,2004; Warning, 2004; Johnes, 2006a; Agasisti & Serlano, 2007; Castano & Cabanda, 2011; Johnes, 2008; Worthington & Lee, 2008; Kantabutra & Tang, 2010; Katharaki & Katharakis, 2010; Eckles, 2010; Kempkes & Pohl, 2010; Lee, 2011; Agasisti & Pohl, 2012; Cunha & Rocha, 2012; Sav, 2012; Sav, 2013), income derived for specific purposes (see Ng & Li, 2000; Johnes, 2008; Agasisti & Johnes, 2009; Kantabutra &

Tang, 2010; Agasisti & Perez-Esparrells, 2010; Kempkes & Pohl, 2010; Wolszczak-Derlacz & Partera, 2011; Cunha & Rocha, 2012; Tochkov et al., 2012; Wolszczak-Derlacz, 2014), value of assets and level of investment (see Abbott & Doucouliagos, 2003; Johnes, 2006a; Castano & Cabanda ,2011; Sav, 2013; Tochkov et al., 2012; Wongchai et al., 2012) and numbers of books or computers (see Joumady & Ris, 2005; Johnes, 2008; Sav, 2012; Tochkov et al., 2012) were used as a measure of physical capital input.

However, the financial data of HEIs as mentioned above is hardly to acquire in Thai HE system, this study simply employs the numbers of computer and registered Wi-Fi (COMP) as a proxy of physical-capital inputs.

2) Teaching Outputs. There is considerable disagreement among researchers as to what is the best way to quantify the output of teaching activities. Hence, the common measures of teaching outputs used in previous studies were concentrated on the number of graduates in undergraduate and graduate level (see Beasley, 1995; Athanassopoulos & Shale, 1997; Abbott & Doucouliagos, 2003; Flegg et al., 2004; Warning, 2004; Johnes, 2006a; Worthington & Lee, 2008; Agasisti and Johnes, 2009; Kantabutra & Tang, 2010; Wolszczak-Derlacz & Partera, 2011; Agasisti & Pohl, 2012; Wolszczak-Derlacz, 2014). Thus, in this study, the number of Master and Doctoral degree graduates (MDG) is employed to represent the quantity of teaching output. Additionally, since production of graduates in the following 4 fields: medicine, dentistry, pharmaceutical science, and engineering is rather costly than other fields, then, it is reasonable to put the number of graduates in four fields (G4F) into teaching efficiency model for investigating the efficiency in transforming inputs to outputs.

The number of students graduating or achieving a particular qualification cannot indicate all the skills which might be considered as outcomes of education as increasing in students' productivity in labourr market is another aspect to reflect an additional teaching output. Some empirical studies used graduates' employment rate (See Avkiran, 2001; Kantabutra & Tang, 2010; Tochkov et al., 2012), graduates' earnings (Colbert et al., 2000; Tochkov et al., 2012), competency matching (Joumady & Ris, 2005), and employer's satisfaction (Colbert et al., 2000) as proxies of rising in students' productivity. As a result, to capture the skills which might be considered as outcomes of education, the percentage of employed Bachelor degree graduates within 1 year (PEREBG) and the employer satisfaction score to all levels graduates (SATSC) are included to represent quality aspect of teaching output. The inputs and outputs mix for teaching efficiency model used in this study is shown in Table 4.1.

Table 4.1 Inputs and Outputs for Teaching Efficiency Model

DEA models	Inputs	Outputs
Teaching efficiency model	1) FTEs student numbers (FTEST) Number of academic staffs holding assistance professor or higher (ACSTWAP) 2) Number of non-academic staff (NACST) 3) Number of computer and registered Wi-Fi (COMP)	**Quantitative measure** 1) Number of Master and Doctoral degree graduates (MDG) 2) Number of graduates in four fields (medicine, dentistry, pharmaceutical science, and engineering) (G4F) **Qualitative measure** 1) Percentage of employed Bachelor degree graduates within 1 year (PEREBG) 2) Employer satisfaction score to all levels graduates (SATSC)

4.1.4.2 Research Efficiency Model

1) Research Inputs. Research inputs utilized in the research efficiency model are discussed below. In order to reflect academic staff time for research activities, the ratio of FTEs to academic staff (FTESPACST) is utilized as a measure of human-capital input. Additionally, the number of academic staffs holding assistance professor or higher (ACSTWAP) is considered as a measure of academic staffs' quality based upon the assumption that the promoted academic staff (in terms of higher academic position and/or HE level) is more productive in performing a research. These are similar to measures used in previous empirical studies (Breu & Raab, 1994 and Johnes & Li, 2008). The premise underlying academic staffs' quality is based on Johnes and Li (2008) that the promoted academic staff (assistance,

associate and full professors) are more productive than their colleagues. However, it may be a case that those academic staffs were promoted during an era when research demands were less than the current case; or that, after promoting, the faculty has less motivation to be ongoing productive.

Moreover, a research can be produced in association with postgraduate students. The ideal measures to reflect this aspect would be based on a number of Master and doctoral students. Therefore, the number of graduate student (GST) is included into DEA model as the measures of research input.

Similar to teaching efficiency model, since HEIs financial data are hard to acquire, this study simply employs the number of computer and registered Wi-Fi (COMP) as a proxy of physical-capital input. Additionally, the roles of non-academic staff are also important in supporting academic staffs for research activities that the number of non-academic staff (NACST) is also taken as another input of HE production for the research work.

2) Research Outputs. As discussed in a large number of studies, measuring HEIs research output confronts many difficulties. The main reason of these difficulties is that the research produced in HEIs is an intangible asset which is hard to evaluate its values. Moreover, research output has many characteristics causing the complexity to its measure such as productivity, quality, eminence, impact and progress, since different measures capture different aspects of the activity (Johnes & Li, 2008). According to Mcmillan and Chan (2006), a measure that correctly reveals the quantity and quality of research output across a wide and variable range of disciplines within and across HEIs would be preferred (Mcmillan & Chan, 2006).

Mostly empirical studies use number of publications (see Cherchye & Abeele, 2005; Groot & Gracia-Valderrama, 2006; Johnes & Li, 2008; Worthington & Lee, 2008; Aubyn et al., 2009; Kantabutra & Tang, 2010; Wolszczak-Derlacz & Partera, 2011; and Lee, 2011) as a quantitative measure to capture the total volume of research activity.

In this study, the number of publication including all articles published in: 1) the proceedings of a national/an international academic conference, or in a nationally-renowned academic journal that is listed in the TCI database; 2) a nationally-renowned academic journal that is listed in ONESQA pronouncements; 3) an internationally-renowned academic journal listed in the SJR database (SCImago Journal Rank: www.scimagojr.com) that ranks academic journals, and during the most recent year, the journal was listed in the 3rd or 4th quartiles for the article's subject category; or publication in an internationally-renowned academic journal that is listed in ONESQA pronouncements; 4) article published in an internationally-renowned academic journal listed in the SJR database (SCImago Journal Rank: www.scimagojr.com) that ranks academic journals, and during the most recent year, the journal was listed in the 1st or 2nd quartiles for the article's subject category, or publication in an internationally-renowned academic journal that appears in the ISI global.

In order to assign weight to four publications categories regarding the quality aspect, as mentioned above, according to the importance of the publication, this paper applies the similar procedure proposed by OENSQA for evaluating research performance of Thai HEIs using the following aggregate index of publications:

Publications index =1*articles published in category 4 +
0.75*articles published in category 3 +
0.5*articles published in category 2
+0.25*articles published in category 1

Moreover, as graduate students are an input in research production process, graduates' thesis and dissertation should be included as a part of research output. Therefore, publication index used as a measure of research output in this study is composed of the academic staff's publication index (ACSTPID) and the graduate student's publication index (GSTPID).

Inevitable, these indexes have shortcomings. For instance, using a category normalized number of journal publications, as suggested by some authors, allows controlling for the quality and field of research, but, as argued in many studies, the HEIs research output is not limited to journal publications. Conference papers, book reviews, and patents are all variable outputs and simply choosing one biases the results, however, due to the constraint on availability of data regarding other types of research output, this study concentrates on journal publications.

Additionally, to reflect research productivity across the HEI, the ratio of publication numbers to academic staff numbers (PNPACST) is also included. This depends on the argument that the best performing HEIs should have most of its staff actively engaged in research and so would score highly on both ACSTPID and PNPACST. A HEI which has only a small number of active researchers might score relatively high on ACSTPID (and hence perform well in producing volume of research), but would inevitably have a small score on PNPACST (and hence its productivity would be low). These three research output measures, as mentioned above, are similar to measures used by Korhonen et al. (2001) and Johnes and Li (2008).

Furthermore, the percentage of academic staff's research article published in category 4 (PERACSTR4) and the percentage of graduate student's research article published in category 4 (PERGSTR4) should be embraced into the research efficiency model to reflect quality of research output.

Another indicator of research output is research funds. Although, research funding fails to account for the quality and field differences, an advantage of this indicator is that it directly relates to the annual costs. It is more difficult to relate publications and other similar indicators to annual costs since the research conducted in a particular year is usually published in the form of journal paper with some time lag (Daghbashyan, 2012). Many researchers using research funding as a measure of research output also argue that the HEIs ability to generate such funds is closely correlated with its research output (see Cohn, Rhine, & Santos, 1989). However, there is some disagreement on whether research funds should be used as an input or an output. Many empirical studies agree on using the research funds and the amount of money received for financing the research as a good proxy for the value of the research and therefore as an output (see Beasley, 1995; Mcmillan & Datta, 1998; Robst, 2001; Abbot & Doucouliagos, 2003; Flegg et al., 2004; Johnes, 2006a; Agasisti & Salerno, 2007; Johnes, 2008; Worthington & Lee, 2008; Agasisti & Johnes, 2009; Katharaki & Katharakis, 2010; Agasisti & Perez-Esparrells, 2010; Kempkes & Pohl, 2010; Lee, 2011; Agasisti & Pohl, 2012; Sav, 2012; Sav, 2013; Wongchai et al., 2012). However, not all research funds are spent for the purpose of research but also on other facilities which should be identified as research inputs, thus, research funds do not completely reflect the research output but income for other research activities (Johnes & Johnes, 1993). Based on this argument, there are few empirical studies classifying a research grants, incomes, or expenditures in HE sector as an input measures, for example, Athanassopoulos and Shale (1997), Korhonen et al. (2001), Johnes and Li (2008), Kantabutra and Tang (2010), and Tochkov et al. (2012). In agreement with the main part of the empirical studies, this study uses the research funds from external sources (EXRF), mainly from government agencies, as a research output. The input and output mix for research efficiency model is shown in Table 4.2.

Table 4.2 Inputs and Outputs for Research Efficiency Model

DEA Models	Inputs	Outputs
Research efficiency model	1) Ratio of FTEs to academic staff (FTESPACST) 2) Number of academic staffs holding assistance professor or higher (ACSTWAP) 3) Number of graduate students (GST) 4) Number of non-academic staff (ACSTPNACST) 5) Number of computer and registered Wi-Fi (COMP)	**Quantitative measure** 1) Academic staff's publication index (ACSTPID) 2) Graduate student' s publication index(GSTPID) **Qualitative measure** 1) Ratio of academic staff' s publication numbers to academic staff numbers (PNPACST) 2) Percentage of academic staff's research article published in category 4 (PERACSTR4) 3) Percentage of graduate student's research article published in category 4 (PERGSTR4) 4) Research funds from external sources (EXRF)

4.2 Investigation on the Effects of Public Funding on HEIs' Technical Efficiency Using Double Bootstrap Procedure for Two-Stage Data Envelopment Analysis (DEA)

The nonparametric nature of DEA approach brings about a key drawback of using DEA approach in evaluating HEIs' efficiency. That is ignorance of an error term and considering all deviations from the frontier as inefficiency. The technical efficiency score obtained from the DEA approach are, then, not sufficient to detect various reasons of differences in HEIs' efficiency.

Moreover, lacking of uncertainty concern implies that the efficiency of a HEI is affected by only inputs and outputs involved in HE production process which are generally thought to be endogenous and under the control of HEIs' management. Of course, this is not the case since deviations from the frontier may be caused by environment factors beyond any managerial control. These environment factors are categorized into two groups: nondiscretionary inputs/outputs, and the external context (Agasisti, 2011). Logically, the two groups are separated: the former represents variables that must be included into the production process (but they are inputs/outputs that are not under the control of the policymaker); the latter is constituted by factors that are external to the production process but actually influences it.

The most common approach to incorporate these environmental factors into DEA of technical efficiency is the two-stage DEA. In the first stage, the linear programming problem is solved to obtain an efficiency score, and afterwards, in the second stage, the computed efficiency scores from the first stage are regressed on the environment factors that would not be part of the production directly but are believed to affect HEIs' efficiency in producing the outputs from the inputs that are included in the first stage. Unfortunately, the division between management and environmental factors is not always distinct. Generally, however, the actual inputs and outputs belong in the DEA while factors explaining the efficiency with which inputs produce outputs belong in the regression (Fried et al., 1993).

The regression model for the above purposes, in the second stage, can be expressed as follow:

Teaching Model $\hat{\phi}_j^T = E_j\beta^T + \varepsilon_j$ (4.6)

Research Model $\hat{\phi}_{jt}^R = E_j\beta^R + \varepsilon_j$ (4.7)

Where $\hat{\phi}_{jt}^T$: Teaching- efficiency score of HEI j, $\hat{\phi}_{jt}^R$: Research- efficiency score of HEI j, E: Vector of environmental factors affecting efficiency of HEIs j, β: Vector of environmental factors coefficient, ε_j: Statistic error noise with the distribution restricted by: $\varepsilon_j > 1 - E_j\beta$, since DEA efficiency scores are larger than or equal to one in the output-orientation approach.

However, the two-stage approach has been criticized by Simar and Wilson (2007) in four ways: Firstly, the DEA-efficiency scores obtained by solving the linear programming problem are serially correlated (in finite samples) since they depend on the same best practice frontier. This means that error terms of the second stage regression are serially correlated as well. Therefore, using these DEA-efficiency scores in a second stage regression might violate the basic assumptions required by the regression model. Secondly, since environmental factors are correlated with the inputs and outputs (otherwise there would be no need for a second stage regression), the environmental variables must also be correlated with the error term of the second stage regression. Indeed, both correlations disappear asymptotically, but only at a slow rate. Thirdly, the DEA efficiency scores obtained by solving the linear programming problem are biased towards one in small samples. Finally, due to the deterministic nature of DEA estimation (omission of random error), DEA-efficiency score is criticized for the inability to perform statistical testing regarding the estimated efficiency score. To improve the statistical efficiency of the parameter estimator in the second stage regression, Simar and Wilson (2007) suggest a double bootstrap procedure (called Algorithm #2) where, in the first stage, a set of bias-corrected DEA-efficiency scores and confidence intervals is generated by the first bootstrap procedure. Subsequently, standard errors of the estimated coefficients in the second stage regression of the bias-corrected DEA-efficiency on the environmental variables are constructed by the second bootstrap procedure. After that, confidence intervals for the regression estimated coefficients are created. Moreover, they suggest that the second stage regression should be conducted by a truncated maximum likelihood regression instead of a censored regression since the efficiency scores are truncated (at one) by construction and not because of censoring. Therefore, the truncated regression model of the bias-corrected DEA-efficiency on the environmental variables can be written as:

Teaching Model $\hat{\hat{\phi}}_{jt}^{T} = E_j\beta^{T} + \varepsilon_j$ (4.8)

Research Model $\hat{\hat{\phi}}_{jt}^{R} = E_j\beta^{R} + \varepsilon_j$ (4.9)

Where $\hat{\hat{\phi}}_j^{T} = \hat{\phi}_j^{T} - \text{bias}(\hat{\phi}_j^{T})$ and $\hat{\hat{\phi}}_j^{R} = \hat{\phi}_j^{R} - \text{bias}(\hat{\phi}_j^{R})$ are the biased-corrected estimator of $\hat{\phi}_j^{T}$and $\hat{\phi}_j^{R}$, respectively.

For the sake of simplicity, the double bootstrap procedure following the Algorithm #2 by Simar and Wilson (2007) is explained regardless of the types of efficiency model (teaching and research efficiency model) as follow:

1) Using the original sample of observed data to calculates the output-oriented DEA technical efficiency scores $\hat{\phi}_j$, j = 1, …, N.

2) Use the method of maximum likelihood to obtain an estimate $\hat{\beta}$of β in the truncated regression of $\hat{\phi}_j$ on E_j in (4.9)/ (4.10) using the m < N observations when $0 < \hat{\phi}_j$<1.

3) Loop the next four steps ((3.1)-(3.4)) L1 = 100 times to obtain a set of bootstrap estimates: $= \{\hat{\phi}_j^{*}\}_{b=1}^{100}$, j = 1,…, N.

(1) For each j = 1, …, N , draw ε_j from $N(0, \hat{\sigma}^2)$ distribution with left-truncation at 1-$E_j\hat{\beta}$

(2) Again for each j = 1, …, N, compute $\phi_j^{*} = E_j\hat{\beta} + \varepsilon_j$, j = 1, …, N.

(3) Set $X_j^{*} = X_j$and $Y_j^{*} = Y_j\left[\frac{\hat{\phi}_j}{\phi_j^{*}}\right]$ for all j = 1, …, N.

(4) Use X_j^{*}, Y_j^{*} to estimate $\hat{\phi}_j^{*}$using the DEA estimator.

4) For each j = 1, …, N, compute the biased-corrected estimates $\hat{\hat{\phi}}_j$using the bootstrap estimates in B and the original $\hat{\phi}_j$.

5) Estimate the truncated regression of $\hat{\hat{\phi}}_j$ on E_j to obtain estimates $(\hat{\hat{\beta}}, \hat{\hat{\sigma}}_{\varepsilon})$ of $(\beta, \sigma_{\varepsilon})$, j=1, …, N.

6) Loop over the next three steps ((6.1)- (6.3)) L2 = 2000 times to obtain a set of bootstrap estimates of $\psi = \left\{\hat{\hat{\beta}}^*\right\}_{l=1}^{2000}$.

(1) For each j = 1, …, N, draw ε_{jt} from the $N\left(0, \hat{\hat{\sigma}}^2\right)$ distribution with left-truncated $1 - E_j\hat{\hat{\beta}}$.

(2) Use ε_j for each j = 1, …, N to calculate fitted DEA score: $\phi_j^{**} = E_j\hat{\hat{\beta}} + \varepsilon_j$.

(3) Apply maximum likelihood to estimates the truncated regression of ϕ_j^{**} on E_j to obtain estimates of $\left(\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}_\varepsilon^*\right)$ in a truncated regression.

7) Use the bootstrap value in ψ and the original estimates $\left(\hat{\hat{\beta}}, \hat{\hat{\sigma}}_\varepsilon\right)$ to construct estimated confidence intervals for each element of β and σ_ε. The $(1-\alpha)$ confidence intervals of β_j is constructed by finding values $a_{\alpha/2}$ and $b_{\alpha/2}$ such that

$$Pr\left[-b_{\alpha/2}^* \leq \left(\hat{\hat{\beta}}_j^* - \hat{\hat{\beta}}_j\right) \leq -a_{\alpha/2}^*\right] \approx 1-\alpha$$

4.2.1 Variables Specification

According to the previous studies such as Robst (2001), Kuo and Ho (2008), Aubyn et al. (2009), Wolszczak-Derlacz and Parteka (2011); Daghbashyan (2012); Sav (2013); and Tochkov et al. (2012), public funding for HEIs is considered as an nondiscretionary factor which is beyond the control of HEIs management and is expected to have some influence on efficiency in which HEIs use inputs to produce outputs. Therefore, in order to examine the relationship between public funding for HEIs and HEIs' efficiency, public funding variables are included in to the second stage regression analysis.

In case of Thailand, the significant amount of HEIs revenues is financed by the government and the rest comes from their own income, including tuition and fees, benefits from intellectual properties (such as research & academic services and investment), donations, and others. The government allocation of funds is mainly based on the number of students. Thus, though the HE sector is mainly publicly financed, the share of government support in the total revenues varies across HEIs. To investigate whether public funding for HEIs impacts on HEIs' efficiency, the ratio of public funding to FTEs student numbers (PFPFTES) and the percentage of public funding in all amount of HEIs' revenues (PERPF) are incorporated into the vector of environmental factor (E). In addition, since public funding and HEIs' own income are appropriated according to the five categories of expenditure type: personnel expenses, operating expenses, subsidies expenses, investment expenses, and others, the percentage of HEIs' investment expenditure in all amounts of HEIs' expenditure (PERINEX) is then integrated into the truncated regression model (8) and (9) to deeply scrutinize the effect of public funding for HE on HEIs' efficiency.

Besides public funding variables, there are many other environmental factors which should be included to explain the variation in efficiency across HEIs. For this purpose, five variables are chosen. The options of these variables, together with predictions concerning their impact on HEIs' efficiency scores, are discussed briefly below. Similar to the studies of Kempkes & Pohl (2010) and Wolszczak-Derlacz and Parteka (2011), HEIs' location is chosen to be an important factor in determining their efficiency. The idea is that HEIs which is located in a region of high income can take advantages from positive spillover effects resulting from the cooperation with research intensive companies in the region as well as the existence of laboratories, research institutions and big libraries which might lead to increasing in their efficiency. Therefore, the value of real Gross Regional Product per capita (GRP) in which HEIs located is utilized as a proxy for the characteristics of their location. Moreover, to take into account the specification of faculty composition, a dummy variable for HEIs with medical faculty (MED) is included into the second stage regression analysis. Furthermore, it is commonly recognized that HEIs with a longer tradition have better reputation but it could also be the case that new HEIs have more flexible and modern structures, assuring a more efficient performance. As a result, the age of HEI since its foundation (AGEF) is employed as a proxy of the level of traditional. Moreover, to investigate relationship between HEIs quality and efficiency aspects, internal quality score from HEIs Self-Assessment Report (IQA_ASSC) is included into the second stage regression analysis. Finally, three dummy variables for the institution type (three variables: RM.U, PB.U, and AUTO.U for 4 types) are included to control the difference in HEIs strengths and aspirations.

All variables utilized in the second stage regression analysis are depicted in the Table 4.3, as follow.

Table 4.3 Variables in the Second Stage Regression Analysis

Variable	Teaching Model	Research Model
Dependent variable	The bootstrapped bias-corrected teaching efficiency score (BTEFFSC)	The bootstrapped bias-corrected research efficiency score (BREFFSC)
Independent Variable	1) Ratio of public funding to FTEs student numbers (PFPFTES) 2) Percentage of public funding in all amounts of HEIs' revenues (PERPF) 3) Percentage of HEIs' investment expenditure in all amounts of HEIs' expenditure (PERINEX) 4) Real Gross Regional Product per capita(GRP) 5) Dummy variable for HEIs with medical faculty (MED) 6) Age of HEIs since the period of foundation (AGEF) 7) Internal quality score from Self- Assessment Report (IQA_ASSC) 8) Dummy variable for HEIs type: (1) RM.U- Rajamangala University of Technology (2) PB.U- Public University (3) AUTO.U- Autonomous University	1) Ratio of public funding to FTEs student numbers (PFPFTES) 2) Percentage of public funding in all amounts of HEIs' revenues (PERPF) 3) Percentage of HEIs' investment expenditure in all amounts of HEIs' expenditure (PERINEX) 4) Real Gross Regional Product per capita(GRP) 5) Dummy variable for HEIs with medical faculty (MED) 6) Age of HEIs since the period of foundation (AGEF) 7) Internal quality score from Self- Assessment Report (IQA_ASSC) 8) Dummy variable for HEIs type: (1) RM.U- Rajamangala University of Technology (2) PB.U- Public University (3) AUTO.U- Autonomous University

Therefore, the model estimated in the second stage regression analysis takes on the following form:

Teaching Model:

$$BTEFFSCjt = \beta_0 + \beta_1 PFPFTESjt + \beta_2 PERPFjt + \beta_3 PERINEXjt + \beta_4 GRPjt + \beta_5 MEDj + \beta_6 AGEFjt + \beta_7 IQA\_ASSCjt + \beta_8 RM.Uj + \beta_9 PB.Uj + \beta_{10} AUTO.Uj + \varepsilon jt \quad (4.10)$$

Research Model:

$$BREFFSCjt = \beta_0 + \beta_1 PFPFTESjt + \beta_2 PERPFjt + \beta_3 PERINEXjt + \beta_4 GRPjt + \beta_5 MEDj + \beta_6 AGEFjt + \beta_7 IQA\_ASSCjt + \beta_8 RM.Uj + \beta_9 PB.Uj + \beta_{10} AUTO.Uj + \varepsilon jt \quad (4.11)$$

Practically, to obtain the DEA efficiency scores, this paper utilizes rDEA 1.2-4 software (2016) which is freely available online, and the truncated regression models are then performed in STATA12.

CHAPTER 5

EMPIRICAL RESULTS AND POLICY IMPLICATIONS

In the previous chapter, the method of the two-stage double bootstrap DEA in measuring teaching and research technical efficiency and investigating influences of public funding on teaching and research technical efficiency have already been introduced. This chapter presents the empirical findings on the issues outlined in chapter 4, and the policy implications. Empirical findings are discloses in section 5.1, while the policy implications are revealed in section 5.2. In section 5.1 the following issues are related: 5.1.1 data sample and preliminary descriptive statistics of variables used in the study, 5.1.2 teaching efficiency of Thai Public HEIs, 5.1.3 research efficiency of Thai Public HEIs, 5.1.4 effects of public funding for HE on HEIs' efficiency. In section 5.2, the policy implications from the study are shown. In addition, for briefness, the notion of "efficiency" is clearly used instead of "technical efficiency" for this chapter.

5.1 Empirical Findings

5.1.1 Data and Sample

This study gathers data on public HEIs operating in Thai HE system during the years 2010-2012. The main source of data is Office of Higher Education Commission (OHEC) which provides information on inputs and outputs of HE production. For the purpose of maintaining HEIs' homogeneity, some types of HEIs are excluded from the analysis such as Open University (Ramkhamhaeng University, Sukhothai Thammathirat Open University), Monk University (Mahamakut Buddhist University, Mahachulalongkornrajavidyalaya University), and HEIs which mainly devote to educate and train only for graduate studies level (National Institute of Development Administration). The final sample comprises of 55 public HEIs of which complete data are available for the years of study. The number of HEIs regarding HEI types and groups is presented in Table 5.1. In addition, a complete list included in the study is given in Table 5.2.

The descriptive statistics of input and output variables employed in teaching efficiency model are presented in Table 5.3 which is clearly seen that teaching input and output variables vary across HEIs types. Moreover, Table 5.3 also provides some preliminary ideas about the differences of HEIs across their types to briefly reveal their relative positions. Over the year 2010-2012, public university and autonomous university is on the opposite side of Rajamangala University of Technology and Rajabhat University. On average, public university and autonomous university have a relatively high level of all inputs (the number of FTEs: FTEST, the number of academic staff with assistance professor or higher: ACSTWAP, the number of non-academic staff: NACST, and the number of computer and registered Wi-Fi: COMP) and some outputs (the number of Master and Doctoral degree graduates: MDG, the number of graduates in four fields (medicine, dentistry, pharmaceutical science, and engineering): G4F). In contrast, Rajabhat University and Rajamangala University of Technology are at a relatively low level of all inputs. However, their two outputs are at a relatively high level: percentage of employed Bachelor degree graduates within 1 year (PEREBG) and employer satisfaction score to all levels graduates (SATSC).

The descriptive statistics of research input and output variables are presented in Table 5.4. From this table, it is found that there are four research inputs that are relatively low in Rajabhat University: the number of academic staffs holding assistance professor or higher (ACASTWAP), number of graduate students (GST), the number of non-academic staff (ACSTPNACST), the number of computer and registered Wi-Fi (COMP). On the contrary, those inputs are relatively high in public university and autonomous university, while the remaining research inputs: Ratio of FTEs to academic staff (FTESPACST) is relatively low in public university and autonomous university. Regarding, research outputs, Public University and Autonomous University have a relatively high level of all research outputs (academic staff's publication index (ACSTPID), graduate student's publication index (GSTPID), ratio of academic staff's publication numbers to academic staff numbers (PNPACST), percentage of academic staff's research article published in category 4 (PERACSTR4), percentage of graduate student's research article published in category 4 (PERGSTR4), research funds from external sources (EXRF)), while Rajabhat University and Rajamangala University of Technology have a relatively low level of all research outputs.

Table 5.1 Number of HEIs' Sample by Type and Group

HEIs Type	HEIs Group				Total
	HEIs focusing on undergraduate studies level (B)	**Specialized HEIs focusing on undergraduate studies level (C2)**	**Specialized HEIs focusing on graduate studies level (C1)**	**HEIs focusing on advance research and graduate studies level (D)**	
Rajabhat University (RB)	28	1	-	-	29
Rajamangala University of Technology (RM)	-	6	-	-	6
Autonomous University (AU)	1	1	2	6	10
Public University (P)	2	1	2	5	10
Total	31	9	4	11	55

Source: Office of Higher Education Commission, 2015a.

Table 5.2 Sample of Public HEIs in Thailand 2010-2012

No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group	No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group
1	Kasetsart University	Ku	P	D	29	Mahasarakham Rajabhat University	RMU	RB	B
2	Khon Kaen University	KKU	P	D	30	Yala Rajabhat University	YRU	RB	B
3	Thammasat University	TU	P	D	31	Loei Rajabhat University	LRU	RB	B
4	Naresuan University	NU	P	D	32	Valaya Alongkorn Rajabhat University	VRU	RB	B
5	Maha Sarakham University	MSU	P	B	33	Sisaket Rajabhat University	SSKRU	RB	B
6	Maejo University	MJU	P	C2	34	Songkhla Rajabhat University	SKRU	RB	B
7	Srinakharinwirot University	SWU	P	C1	35	Suan Dusit Rajabhat University	DUSIT	RB	C2
8	Silpakorn University	SU	P	C1	36	Suan Sunandha Rajabhat University	SSRU	RB	B
9	Prince of Songkla University	PSU	P	D	37	Muban Chom Bueng Rajabhat University	MCRU	RB	B
10	Ubonrachathani University	UBU	P	B	38	Uttaradit Rajabhat University	URU	RB	B
11	Kanchanaburi Rajabhat University	KRU	RB	B	39	Ubon Ratchathani Rajabhat University	UBRU	RB	B
12	Kamphaeng Pet Rajabhat University	KPRU	RB	B	40	Rajamangala University of Technology Thanyaburi	RMUTT	RM	C2
13	Chandrakasem Rajabhat University	CHANDRA	RB	B	41	Rajamangala University of Technology Krungthep	RMUTK	RM	C2
14	Chiangrai Rajabhat University	CRRU	RB	B	42	Rajamangala University of Technology Phra Nakhon	RMUTP	RM	C2

Table 5.2 (Continued)

No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group	No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group
15	Chiang Mai Rajabhat University	CMRU	RB	B	43	Rajamangala University of Technology Suvarnabhumi	RMUTSB	RM	C2
16	Nakon Pathom Rajabhat University	NPRU	RB	B	44	Rajamangala University of Technology Rattanakosin	RMUTR	RM	C2
17	Lampang Rajabhat University	LPRU	RB	B	45	Rajamangala University of Technology Isan	RMUTI	RM	C2
18	Nakhon Ratchasima Rajabhat University	NRRU	RB	B	46	Chulalongkorn University	CHULA	AU	D
19	Nakhon Si Thammarat Rajabhat University	NSTRU	RB	B	47	Chiang Mai University	CMU	AU	D
20	Nakhon Sawan Rajabhat University	NSRU	RB	B	48	Taksin University	TSU	AU	B
21	Bansomdejchaopraya Rajabhat University	BSRU	RB	B	49	king Mongkut's University of Technology Thonburi	KMITT	AU	D
22	Buriram Rajabhat University	BRU	RB	B	50	king Mongkut's University of Technology North Bangkok	KMITNB	AU	C1
23	Phranakhon Rajabhat University	PNRU	RB	B	51	Suranaree University of Technology	SUT	AU	D
24	Phranakhon Si Ayutthaya Rajabhat University	ARU	RB	B	52	Burapha University	BBU	AU	D

Table 5.2 (Continued)

No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group	No.	Higher Education Institutions	Abbreviated Name	HEIs Type	HEIs Group
25	Pibulsonghram Rajabhat University	PSRU	RB	B	53	Mahidol University	MAHIDOL	AU	D
26	Phetchaburi Rajabhat University	PBRU	RB	B	54	Walailak University	WU	AU	C2
27	Phetchabun Rajabhat University	PCRU	RB	B	55	king Mongkut's University of Technology Lardkrabang	KMITL	AU	C1
28	Phuket Rajabhat University	PKRU	RB	B					

Source: Office of Higher Education Commission, 2015a.

Note: (1) HEIs' Type includes P: Public University, RB: Rajhabhat University, RM: Rajamangala University of Technology, and AU: Autonomous University.

(2) HEIs' Group includes B: Institutions focusing on undergraduate studies, C2: C2: Specialized institutions focusing on undergraduate studies, C1: Specialized institutions focusing on graduate studies, and D: Institutions focusing on advanced research and production of graduates at the graduate studies levels.

Table 5.3 Teaching Input and Output Variables by HEIs' Type (2010-2012)

Type	Statistic	Input					Output		
		FTEST	ACSTWAP	NACST	COMP	MDG	G4F	PEREBG	SATSC
RB (n=29)	Mean	12,556.08	81.99	369.68	7,066.32	165.06	1.00	80.99	4.26
	S.D.	6,673.81	44.79	248.59	7,269.29	171.13	0.00	10.30	0.40
RM (n=6)	Mean	17,556.11	198.06	672.81	7,804.22	86.33	576.44	86.02	4.23
	S.D.	10,366.82	79.51	255.12	5,767.04	106.99	451.39	5.35	0.20
P (n=10)	Mean	30,274.52	571.54	3,842.55	27,342.24	1,311.20	1,027.87	84.20	4.08
	S.D.	13,852.04	377.10	2,808.46	36,745.55	1,024.15	676.21	5.94	0.20
AU (n=10)	Mean	21,903.47	642.23	4,433.08	17,259.87	1,359.53	1,124.93	83.73	4.14
	S.D.	9,719.28	615.57	7,074.89	15,713.69	1,210.79	670.51	5.30	0.14

Table 5.4 Research Input and Output Variables by HEIs' Type (2010-2012)

Type	Statistic	Input					Output					
		FTESPACST	ACASTWAP	GST	NACAST	PC	ACASTPID	GSTPID	PNPACST	PERACSTR4	PERGSTR4	EXRF
RB	Mean	35.78	81.99	641.86	369.68	7,066.32	26.43	38.41	0.20	10.46	2.37	12.72
(n=29)	S.D.	16.74	44.79	631.64	248.59	7,269.29	19.80	45.21	0.12	10.47	9.04	11.93
RM	Mean	22.86	198.06	408.78	672.81	7,804.22	58.57	23.86	0.19	15.15	3.72	14.25
(n=6)	S.D.	4.84	79.51	453.35	255.12	5,767.04	49.56	36.61	0.10	10.77	10.79	10.26
P	Mean	22.68	571.54	5,136.10	3,842.55	27,342.24	464.13	424.30	0.46	32.52	7.94	459.38
(n=10)	S.D.	6.55	377.10	3,657.37	2,808.46	36,745.55	449.99	380.48	0.21	12.30	7.22	1,030.16
AU	Mean	22.83	642.23	5,591.10	4,433.08	17,259.87	661.68	351.94	0.67	42.01	19.05	398.75
(n=10)	S.D.	12.44	615.57	3,923.17	7,074.89	15,713.69	783.08	363.78	0.25	23.06	22.42	444.05

5.1.2 Teaching Efficiency of Thai Public Higher Education Institutions

5.1.2.1 Teaching Efficiency

The results of using DEA and double-bootstrap DEA to investigate teaching efficiency of Thai public HEIs are reported in Table 5.5. The 1st column indicates HEIs name. The 2nd, 7th and 12th columns show teaching efficiency scores for the year 2010, 2011 and 2012, respectively. The bias-corrected teaching efficiency scores are revealed in the 3rd, 8th and 13th columns. The corresponding bootstrap bias and 95 percent confidence interval for all HEIs over three years are presented in the next three columns. The original teaching efficiency scores are used in the first stage of analysis for the purpose of examining efficiency of Thai HEIs over the year 2010-2012 while, the bias-corrected teaching efficiency scores are employed in the second stage of analysis to investigate the effects of public funding for HE on HEIs' teaching efficiency.

With regard to the original teaching efficiency score, the findings suggest that the majority of Thai public HEIs is inefficient in teaching. Over the periods of study (2010-2012), it is found that only 26.67 % of HEIs are efficient in teaching (see Table 5.6). Each year, the percentage of teaching efficient HEIs decreases from 30.91 % in 2010 to 23.64 % in 2012. Additionally, there are only 8 out of 55 HEIs (14.55 %) are with teaching efficiency HEIs in all three years, including 3 from Rajabhat University, 2 from autonomous university, 2 from public university, and 1 from Rajamangala University of Technology.

When comparing a number of HEIs with teaching efficiency, across HEIs' types, the results as shown in Table 5.6 reveal that autonomous university has a relatively large share of teaching efficient HEIs. On average of over three years, the percentage of the teaching efficient HEIs in this type is about 53.33, followed by public university with the percentage of 30.00. In contrast, Rajabhat University has the relatively lowest share of about 16.09 %.

Regarding the descriptive statistics of teaching efficiency scores as shown in Table 5.7, the results display that, on average over three years, teaching efficiency score of Thai public HEIs is 0.9415, its ranging varies from 0.7580 to 1.0000 with 0.0557 standard deviation. This means that the inefficient HEIs could increase the producing of their teaching outputs (given level of inputs) by 6.21 % in order to be the teaching efficient HEIs. Moreover, the average of teaching efficiency score in each year is slightly stable during three years.

As for HEIs type, Autonomous University has the highest level of average teaching efficiency score in three years (0.9745), followed by Rajamangala University (0.9415). As the type with the highest efficiency score, relative position in inputs and outputs of autonomous university should be recalled. Despite their weaker performance on the inputs side such as the number of academic staff with assistance professor or higher (ACSTWAP), the number of non-academic staff (NACST), and the number of computer and registered Wi-Fi (COMP), they have the highest level of many outputs such as the number of Master and Doctoral degree graduates (MDG), the number of graduates in medicine, dentistry, pharmaceutical science, and engineering (G4F), and employer satisfaction score to all levels graduates (SATSC) (see Table 5.3). On the other hand, the type with the lowest average teaching efficiency score is Rajabhat University as the score is 0.9306. This can be explained by low level of all outputs (see Table 5.3). Therefore, to reach the efficiency level, Rajabhat University require to increase all their outputs level, given inputs level, by 7.45 %.

5.1.2.2 Teaching Scale Efficiency

In this section, the teaching scale efficiency of Thai public HEIs is examined according to the results from solving CCR-DEA and BCC-DEA (teaching) efficiency model as mentioned in section 4.1.1. By solving the two models, two efficiency scores are respectively obtained: teaching overall efficiency and teaching pure efficiency. The ratio of two efficiency scores serves as a measure of teaching scale efficiency. In other words, the teaching scale efficiency score is attained from dividing teaching overall efficiency score by teaching pure efficiency score. Recall that HEIs with teaching scale efficiency score equal to 1 is considered to be teaching scale efficient HEIs, while teaching scale efficiency score less than 1 is deemed to be relatively scale inefficient.

The results of examining the teaching scale efficiency of Thai public HEIs are revealed in Table 5.8 which can be clearly seen that the majority of Thai public HEIs are teaching scale inefficiency. Over three years, the percentage of teaching scale efficient HEIs is only 13.94 percent (see Table 5.9). The results also reveal that the percentage of teaching scale efficient HEIs decreases every year, the percentage diminishes from 20.00 % in 2010 to 7.27 % in 2012. Moreover, all of them are teaching efficient HEIs (Table 5.8). This implies that these HEIs operate on the efficient frontier and achieve to the highest productivity. In other word, teaching efficiency of these HEIs arises from both good management of resources and producing at the optimal scale size. Alternatively, teaching scale inefficient HEIs, over three years, composes of 2 kinds: 21 teaching efficient, accounted for 12.73 %, and 121 teaching inefficient HEIs, accounted for 47.73 % (see Figure 5.1). This implies that 12.73 % of the teaching efficient HEIs operate on the efficient frontier but unable to attain the highest productivity, while 47.73 % of the teaching inefficient HEIs, cannot operate on the efficient frontier as well as achieve the highest productivity.

To compare the percentage of teaching scale efficient HEIs across the Type, the results in Table 5.9 also reveal that autonomous university has the largest share of 30.00 % followed by Rajabhat University (11.49 %). In contrast, public university has the lowest share of only 6.67 %.

Regarding teaching scale efficiency score, the average score of Thai public HEIs, as presented in Table 5.10, is rather low (0.6468). Moreover, it is lower than the average teaching efficiency score (0.9415) (see Table 5.7 and 5.10). This indicates that teaching inefficiency of Thai public HEIs is mainly caused by inappropriate production scale. In order to become more teaching efficiency, these HEIs is required to increase their production of teaching outputs (given the inputs level) by 6.21 % and to adjust their scale of production (given the same mix of inputs and outputs) by 51.18 %.

To compare teaching scale efficiency score across HEIs types, the average teaching scale efficiency score is computed across year types, as shown in Table 5.10. The results reveal that autonomous university has the highest level of average teaching scale efficiency scores (0.8401), followed by Rajamangala University of Technology (0.6583). Rajabhat University shows the lowest level of 0.5916. Their average of teaching scale efficiency score is lower than the one of teaching efficiency score (0.9306). This implies that teaching inefficiency of Rajabhat University is mainly driven by scale of production. To reach the efficiency frontier at the highest level of productivity, they need to alter their scale of production (given the same mix of inputs and outputs) by 69.03 % and to expand their teaching outputs (given the inputs level) only by 7.46 %.

5.1.2.3 Return to Scale of Teaching Production

As mentioned in section 5.1.2.2, the key source of teaching inefficiency in the Thai HE system seems to be scale related. In this section, sources of teaching scale inefficiency are investigated by identifying returns to scale in producing teaching outputs.

The returns to scale of teaching production is detected by using Färe and Grosskopf (1985)'s scale efficiency index. The empirical findings, as presented in Table 5.11 and Figure 5.2, clearly indicate that all teaching scale inefficient HEIs exhibit DRS in producing teaching outputs. This implies that Thai public HEIs are deemed to be operated above the optimal scale of teaching production. Therefore, they could increase the level of productivity by reducing their size of operation. Table 5.11 also depicted the nature of RTS of HEIs across all types and it is obviously seen that greater part of HEIs in each type operates at DRS.

Table 5.5 Teaching Efficiency Score by Year and HEIs' Type

HEIs	2010					2011					2012				
	Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
Ku	1.0000	0.9404	0.0596	0.8928	0.9958	1.0000	0.9306	0.0694	0.8756	1.0057	1.0000	0.9515	0.0485	0.9122	1.0271
KKU	0.9462	0.9196	0.0266	0.8970	0.9429	1.0000	0.9499	0.0501	0.9064	0.9924	1.0000	0.9770	0.0230	0.9578	0.9952
TU	0.9254	0.9035	0.0219	0.8862	0.9220	0.9530	0.9289	0.0242	0.9104	0.9521	0.9631	0.9413	0.0218	0.9226	0.9573
NU	0.9478	0.9129	0.0349	0.8859	0.9446	1.0000	0.9234	0.0766	0.8599	1.0199	0.9216	0.8977	0.0239	0.8788	0.9120
MSU	1.0000	0.9155	0.0845	0.8510	1.0069	1.0000	0.9513	0.0487	0.9144	0.9912	1.0000	0.9499	0.0501	0.9083	0.9885
MJU	0.8262	0.8101	0.0161	0.7999	0.8205	0.9074	0.8900	0.0174	0.8798	0.9015	0.8326	0.8207	0.0119	0.8134	0.8296
SWU	0.8867	0.8637	0.0230	0.8510	0.8730	0.9255	0.9048	0.0207	0.8875	0.9195	0.9264	0.9138	0.0126	0.9039	0.9245
SU	0.9630	0.9458	0.0173	0.9336	0.9569	0.9490	0.9268	0.0223	0.9095	0.9417	0.9773	0.9519	0.0254	0.9307	0.9695
PSU	0.9053	0.8833	0.0220	0.8665	0.8998	0.9126	0.8944	0.0182	0.8779	0.9050	0.9131	0.8937	0.0193	0.8791	0.9074
UBU	0.8427	0.8229	0.0198	0.8121	0.8369	0.8807	0.8578	0.0229	0.8412	0.8806	0.9034	0.8813	0.0222	0.8627	0.8957
KRU	1.0000	0.9246	0.0754	0.8634	1.0137	1.0000	0.9419	0.0581	0.8912	1.0571	1.0000	0.9246	0.0754	0.8632	1.0178
KPRU	0.9498	0.9139	0.0358	0.8884	0.9466	0.9153	0.8810	0.0342	0.8548	0.9149	0.8989	0.8671	0.0318	0.8445	0.8998
CHANDRA	0.9436	0.9178	0.0259	0.9005	0.9388	0.9050	0.8884	0.0167	0.8765	0.9003	0.9237	0.9083	0.0155	0.8986	0.9193
CRRU	0.8933	0.8714	0.0219	0.8555	0.8946	0.8475	0.8325	0.0150	0.8213	0.8439	0.8414	0.8226	0.0189	0.8091	0.8378
CMRU	0.8703	0.8538	0.0165	0.8413	0.8679	0.8557	0.8293	0.0264	0.8068	0.8554	0.8200	0.7980	0.0220	0.7811	0.8111
NPRU	0.9581	0.9254	0.0327	0.8983	0.9498	0.9576	0.9268	0.0308	0.9014	0.9485	0.9388	0.9137	0.0251	0.8932	0.9363
LPRU	1.0000	0.9342	0.0658	0.8796	0.9876	0.9705	0.9280	0.0424	0.8911	0.9600	0.9604	0.9290	0.0314	0.9081	0.9550
NRRU	0.7580	0.7382	0.0199	0.7225	0.7542	0.8066	0.7934	0.0133	0.7828	0.8036	0.8655	0.8527	0.0128	0.8428	0.8646
NSTRU	0.7958	0.7714	0.0244	0.7579	0.7884	0.8043	0.7781	0.0262	0.7598	0.7932	0.8641	0.8401	0.0240	0.8200	0.8679
NSRU	0.9372	0.9154	0.0217	0.8976	0.9349	0.9280	0.9084	0.0196	0.8909	0.9257	0.9113	0.8904	0.0209	0.8774	0.9066
BSRU	1.0000	0.9423	0.0577	0.8944	1.0319	0.9365	0.9060	0.0305	0.8826	0.9319	0.9735	0.9348	0.0386	0.9017	1.0006

Table 5.5 (Continued)

HEIs	2010					2011					2012				
	Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
BRU	0.9553	0.9249	0.0303	0.9042	0.9426	0.8775	0.8548	0.0227	0.8353	0.8799	0.9298	0.9130	0.0169	0.9003	0.9316
PNRU	0.9607	0.9346	0.0261	0.9128	0.9772	0.9912	0.9701	0.0210	0.9545	0.9911	0.8894	0.8742	0.0152	0.8622	0.8928
ARU	0.9465	0.9056	0.0408	0.8705	0.9556	0.9870	0.9528	0.0342	0.9239	0.9901	0.9696	0.9324	0.0372	0.9018	0.9632
PSRU	0.9223	0.8994	0.0229	0.8817	0.9222	0.9437	0.9191	0.0246	0.8998	0.9413	0.9009	0.8820	0.0190	0.8695	0.8987
PBRU	0.9706	0.9414	0.0292	0.9200	0.9642	0.9298	0.8993	0.0305	0.8763	0.9245	0.9437	0.9062	0.0375	0.8779	0.9303
PCRU	0.9900	0.9470	0.0431	0.9114	0.9778	1.0000	0.9360	0.0640	0.8914	0.9785	0.9741	0.9297	0.0444	0.8953	0.9580
PKRU	0.9868	0.9514	0.0354	0.9266	0.9829	0.9054	0.8661	0.0393	0.8338	0.9079	0.9609	0.9162	0.0447	0.8821	0.9550
RMU	0.9323	0.9080	0.0243	0.8903	0.9347	0.8997	0.8720	0.0277	0.8476	0.9106	0.8944	0.8675	0.0269	0.8454	0.9034
YRU	0.9362	0.9053	0.0308	0.8786	0.9370	0.9776	0.9472	0.0305	0.9210	0.9761	0.9621	0.9289	0.0331	0.9054	0.9552
LRU	0.9101	0.8831	0.0271	0.8641	0.9115	0.8767	0.8469	0.0298	0.8226	0.8843	0.8620	0.8318	0.0301	0.8121	0.8538
VRU	1.0000	0.9504	0.0496	0.9093	0.9807	0.9577	0.9292	0.0284	0.9049	0.9598	0.8525	0.8307	0.0218	0.8123	0.8493
SSKRU	1.0000	0.8678	0.1322	0.7938	0.9450	1.0000	0.8771	0.1229	0.7995	0.9648	1.0000	0.8873	0.1127	0.8205	0.9655
SKRU	0.8661	0.8492	0.0168	0.8367	0.8636	0.9685	0.9531	0.0154	0.9392	0.9685	0.9576	0.9396	0.0180	0.9271	0.9578
DUSIT	0.9166	0.9029	0.0137	0.8918	0.9153	0.8434	0.8241	0.0193	0.8095	0.8425	0.8935	0.8713	0.0221	0.8524	0.8904
SSRU	0.8880	0.8619	0.0260	0.8404	0.8937	0.9739	0.9538	0.0201	0.9367	0.9779	0.8660	0.8434	0.0227	0.8226	0.8634
MCRU	1.0000	0.9313	0.0687	0.8764	1.0206	1.0000	0.9404	0.0596	0.8916	1.0356	1.0000	0.9426	0.0574	0.8958	1.0032
URU	0.9826	0.9458	0.0368	0.9174	0.9847	0.9911	0.9501	0.0409	0.9139	0.9906	0.9805	0.9285	0.0519	0.8877	0.9755
UBRU	0.8129	0.7872	0.0256	0.7657	0.8127	0.9927	0.9637	0.0290	0.9410	1.0068	1.0000	0.9792	0.0208	0.9630	1.0010
RMUTT	0.9584	0.9184	0.0401	0.8855	0.9596	1.0000	0.9517	0.0483	0.9102	0.9773	0.9877	0.9742	0.0136	0.9638	0.9925
RMUTK	0.9356	0.9142	0.0214	0.9013	0.9310	0.9286	0.9075	0.0211	0.8909	0.9301	0.9049	0.8834	0.0215	0.8661	0.9042

Table 5.5 (Continued)

HEIs	2010					2011					2012				
	Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score				Original Teaching Efficiency Score	Bootstrapped Teaching Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
RMUTP	0.9185	0.8931	0.0254	0.8727	0.9107	0.9226	0.9004	0.0222	0.8813	0.9137	0.9759	0.9551	0.0208	0.9373	0.9716
RMUTSB	0.8687	0.8380	0.0308	0.8123	0.8653	0.8622	0.8431	0.0190	0.8315	0.8580	0.8530	0.8334	0.0197	0.8198	0.8438
RMUTR	1.0000	0.9250	0.0750	0.8676	1.0117	0.9033	0.8744	0.0289	0.8492	0.9030	0.9256	0.9037	0.0220	0.8903	0.9180
RMUTI	1.0000	0.9419	0.0581	0.8935	0.9924	1.0000	0.9421	0.0579	0.8944	0.9799	1.0000	0.9598	0.0402	0.9321	0.9853
CHULA	1.0000	0.9534	0.0466	0.9145	1.0572	1.0000	0.9628	0.0372	0.9304	1.0340	1.0000	0.9726	0.0274	0.9505	1.0286
CMU	0.9551	0.9408	0.0143	0.9286	0.9517	0.9432	0.9279	0.0153	0.9142	0.9402	0.8978	0.8826	0.0152	0.8705	0.8947
TSU	0.8745	0.8463	0.0282	0.8224	0.8907	0.8964	0.8720	0.0244	0.8536	0.8951	0.9855	0.9411	0.0444	0.9058	1.0167
KMITT	1.0000	0.9558	0.0442	0.9181	1.0234	0.9864	0.9620	0.0244	0.9401	0.9994	1.0000	0.9586	0.0414	0.9225	1.0153
KMITNB	1.0000	0.9408	0.0592	0.8908	1.0593	1.0000	0.9427	0.0573	0.8945	1.0204	0.9835	0.9536	0.0299	0.9316	0.9868
SUT	1.0000	0.9620	0.0380	0.9282	1.0232	1.0000	0.9605	0.0395	0.9266	1.0596	1.0000	0.9550	0.0450	0.9158	1.0287
BUU	1.0000	0.9301	0.0699	0.8760	0.9853	0.9523	0.9217	0.0306	0.8944	0.9560	1.0000	0.9560	0.0440	0.9178	1.0340
MAHIDOL	1.0000	0.9654	0.0346	0.9335	0.9948	1.0000	0.9677	0.0323	0.9396	1.0031	0.9592	0.9386	0.0206	0.9238	0.9566
WU	0.9271	0.8925	0.0346	0.8618	0.9318	0.9742	0.9361	0.0381	0.9020	0.9901	0.9151	0.8862	0.0289	0.8640	0.9157
KMITL	1.0000	0.9344	0.0656	0.8797	1.0121	0.9845	0.9552	0.0294	0.9282	0.9914	1.0000	0.9646	0.0354	0.9348	0.9956

Table 5.6 Number and Percentage of Teaching Efficient HEIs by Year and HEIs' Type

Type	2010		2011		2012		2010-2012 (n =165)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
RB (n=29)	6.00	20.69	4.00	13.79	4.00	13.79	14.00	16.09
RM (n=6)	2.00	33.33	2.00	33.33	1.00	16.67	5.00	27.78
P (n=10)	2.00	20.00	4.00	40.00	3.00	30.00	9.00	30.00
AU (n=10)	7.00	70.00	4.00	40.00	5.00	50.00	16.00	53.33
Total (n= 55)	17.00	30.91	14.00	25.45	13.00	23.64	44.00	26.67

Table 5.7 Descriptive Statistics of Teaching Efficiency Scores by Year and HEIs' Type

Type	Statistic	2010	2011	2012	2010-2012
	Min.	0.7580	0.8043	0.8200	0.7580
	Max.	1.0000	1.0000	1.0000	1.0000
RB	**Mean**	**0.9339**	**0.9325**	**0.9253**	**0.9306**
	S.D.	0.0644	0.0603	0.0536	0.0591
	n	29.0000	29.0000	29.0000	87.0000
	Min.	0.8687	0.8622	0.8530	0.8530
	Max.	1.0000	1.0000	1.0000	1.0000
RM	**Mean**	**0.9469**	**0.9361**	**0.9412**	**0.9414**
	S.D.	0.0506	0.0547	0.0569	0.0510
	n	6.0000	6.0000	6.0000	18.0000
	Min.	0.8262	0.8807	0.8326	0.8262
	Max.	1.0000	1.0000	1.0000	1.0000
P	**Mean**	**0.9243**	**0.9528**	**0.9438**	**0.9403**
	S.D.	0.0597	0.0454	0.0545	0.0530
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.8745	0.8964	0.8978	0.8745
	Max.	1.0000	1.0000	1.0000	1.0000
AU	**Mean**	**0.9757**	**0.9737**	**0.9741**	**0.9745**
	S.D.	0.0437	0.0340	0.0381	0.0375
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.7580	0.8043	0.8200	0.7580
	Max.	1.0000	1.0000	1.0000	1.0000
Total	**Mean**	**0.9412**	**0.9441**	**0.9393**	**0.9415**
	S.D.	0.0600	0.0544	0.0535	0.0557
	n	55.0000	55.0000	55.0000	165.0000

Table 5.8 Teaching Scale Efficiency and HEIs' Return to Scale of Teaching Production

HEIs	2010				2011				2012			
	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS
KU	0.6952	1.0000	0.6952	DRS	0.6860	1.0000	0.6860	DRS	0.6355	1.0000	0.6355	DRS
KKU	0.3972	0.9462	0.4198	DRS	0.7982	1.0000	0.7982	DRS	0.6037	1.0000	0.6037	DRS
TU	0.5683	0.9254	0.6141	DRS	0.6305	0.9530	0.6616	DRS	0.5895	0.9631	0.6121	DRS
NU	0.8550	0.9478	0.9021	DRS	1.0000	1.0000	1.0000	CRS	0.7425	0.9216	0.8056	DRS
MSU	1.0000	1.0000	1.0000	CRS	0.7199	1.0000	0.7199	DRS	0.7210	1.0000	0.7210	DRS
MJU	0.3560	0.8262	0.4309	DRS	0.3018	0.9074	0.3326	DRS	0.2825	0.8326	0.3392	DRS
SWU	0.5464	0.8867	0.6162	DRS	0.5049	0.9255	0.5456	DRS	0.2823	0.9264	0.3047	DRS
SU	0.4377	0.9630	0.4545	DRS	0.5161	0.9490	0.5438	DRS	0.5913	0.9773	0.6050	DRS
PSU	0.3806	0.9053	0.4204	DRS	0.3556	0.9126	0.3897	DRS	0.3851	0.9131	0.4217	DRS
UBU	0.5172	0.8427	0.6138	DRS	0.6655	0.8807	0.7556	DRS	0.4909	0.9034	0.5434	DRS
KRU	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
KPRU	0.5978	0.9498	0.6294	DRS	0.6041	0.9153	0.6600	DRS	0.4988	0.8989	0.5549	DRS
CHANDRA	0.5128	0.9436	0.5434	DRS	0.3117	0.9050	0.3444	DRS	0.3018	0.9237	0.3267	DRS
CRRU	0.4270	0.8933	0.4780	DRS	0.2096	0.8475	0.2474	DRS	0.3748	0.8414	0.4455	DRS
CMRU	0.3261	0.8703	0.3747	DRS	0.5617	0.8557	0.6564	DRS	0.2448	0.8200	0.2985	DRS
NPRU	0.5229	0.9581	0.5458	DRS	0.4946	0.9576	0.5165	DRS	0.4029	0.9388	0.4292	DRS
LPRU	0.9787	1.0000	0.9787	DRS	0.6670	0.9705	0.6873	DRS	0.6789	0.9604	0.7069	DRS
NRRU	0.2706	0.7580	0.3570	DRS	0.2580	0.8066	0.3198	DRS	0.3010	0.8655	0.3478	DRS
NSTRU	0.3902	0.7958	0.4903	DRS	0.3906	0.8043	0.4857	DRS	0.4088	0.8641	0.4731	DRS
NSRU	0.5057	0.9372	0.5395	DRS	0.3993	0.9280	0.4303	DRS	0.3653	0.9113	0.4009	DRS
BSRU	1.0000	1.0000	1.0000	CRS	0.5752	0.9365	0.6142	DRS	0.7915	0.9735	0.8131	DRS
BRU	0.4854	0.9553	0.5081	DRS	0.5401	0.8775	0.6154	DRS	0.3650	0.9298	0.3926	DRS
PNRU	0.4909	0.9607	0.5110	DRS	0.3354	0.9912	0.3384	DRS	0.3165	0.8894	0.3559	DRS

Table 5.8 (Continued)

HEIs	2010				2011				2012			
	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS
ARU	0.6909	0.9465	0.7300	DRS	0.7744	0.9870	0.7845	DRS	0.6431	0.9696	0.6633	DRS
PSRU	0.4021	0.9223	0.4360	DRS	0.4754	0.9437	0.5037	DRS	0.3573	0.9009	0.3966	DRS
PBRU	0.5928	0.9706	0.6108	DRS	0.5099	0.9298	0.5484	DRS	0.5599	0.9437	0.5933	DRS
PCRU	0.7894	0.9900	0.7973	DRS	1.0000	1.0000	1.0000	CRS	0.6337	0.9741	0.6506	DRS
PKRU	0.7390	0.9868	0.7489	DRS	0.5454	0.9054	0.6024	DRS	0.6065	0.9609	0.6312	DRS
RMU	0.5376	0.9323	0.5766	DRS	0.5457	0.8997	0.6065	DRS	0.5233	0.8944	0.5851	DRS
YRU	0.6931	0.9362	0.7404	DRS	0.6631	0.9776	0.6783	DRS	0.6811	0.9621	0.7079	DRS
LRU	0.4749	0.9101	0.5217	DRS	0.6267	0.8767	0.7149	DRS	0.5014	0.8620	0.5817	DRS
VRU	0.6164	1.0000	0.6164	DRS	0.7185	0.9577	0.7502	DRS	0.6076	0.8525	0.7127	DRS
SSKRU	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
SKRU	0.3781	0.8661	0.4366	DRS	0.3287	0.9685	0.3394	DRS	0.3267	0.9576	0.3411	DRS
DUSIT	0.2760	0.9166	0.3012	DRS	0.3008	0.8434	0.3567	DRS	0.3023	0.8935	0.3384	DRS
SSRU	0.3814	0.8880	0.4296	DRS	0.3871	0.9739	0.3975	DRS	0.3256	0.8660	0.3760	DRS
MCRU	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	0.7461	1.0000	0.7461	DRS
URU	0.5758	0.9826	0.5860	DRS	0.6504	0.9911	0.6563	DRS	0.6598	0.9805	0.6729	DRS
UBRU	0.4285	0.8129	0.5272	DRS	0.6801	0.9927	0.6851	DRS	0.3752	1.0000	0.3752	DRS
RMUTT	0.9365	0.9584	0.9771	DRS	0.7367	1.0000	0.7367	DRS	0.2895	0.9877	0.2931	DRS
RMUTK	0.5469	0.9356	0.5845	DRS	0.6031	0.9286	0.6495	DRS	0.6206	0.9049	0.6858	DRS
RMUTP	0.5221	0.9185	0.5684	DRS	0.5532	0.9226	0.5997	DRS	0.5196	0.9759	0.5324	DRS
RMUTSB	0.6454	0.8687	0.7429	DRS	0.5007	0.8622	0.5807	DRS	0.4398	0.8530	0.5156	DRS
RMUTR	1.0000	1.0000	1.0000	CRS	0.5552	0.9033	0.6146	DRS	0.4722	0.9256	0.5102	DRS
RMUTI	1.0000	1.0000	1.0000	CRS	0.6485	1.0000	0.6485	DRS	0.6099	1.0000	0.6099	DRS
CHULA	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	0.9505	1.0000	0.9505	DRS

Table 5.8 (Continued)

HEIs	2010				2011				2012			
	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS	Teaching Overall Efficiency (DEA-CCR model)	Teaching Pure Efficiency (DEA-BCC model)	Teaching Scale Efficiency	RTS
CMU	0.3847	0.9551	0.4028	DRS	0.5349	0.9432	0.5671	DRS	0.5067	0.8978	0.5644	DRS
TSU	0.7720	0.8745	0.8828	DRS	0.3975	0.8964	0.4435	DRS	0.9510	0.9855	0.9650	DRS
KMITT	1.0000	1.0000	1.0000	CRS	0.9320	0.9864	0.9448	DRS	0.9861	1.0000	0.9861	DRS
KMITNB	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	0.8381	0.9835	0.8522	DRS
SUT	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
BUU	0.8433	1.0000	0.8433	DRS	0.8423	0.9523	0.8845	DRS	1.0000	1.0000	1.0000	CRS
MAHIDOL	0.8080	1.0000	0.8080	DRS	0.7296	1.0000	0.7296	DRS	0.4414	0.9592	0.4602	DRS
WU	0.8373	0.9271	0.9031	DRS	0.9686	0.9742	0.9942	DRS	0.5717	0.9151	0.6248	DRS
KMITL	0.9738	1.0000	0.9738	DRS	0.6467	0.9845	0.6568	DRS	0.7659	1.0000	0.7659	DRS

Table 5.9 Number and Percentage of Teaching Scale Efficient HEIs by Year and HEIs' Type

Type	2010		2011		2012		2010-2012 (n =165)	
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
RB (n=29)	**4**	**13.79**	**4**	**13.79**	**2**	**6.90**	**10**	**11.49**
RM (n=6)	**2**	**33.33**	**0**	**0.00**	**0**	**0.00**	**2**	**11.11**
P (n=10)	**1**	**10.00**	**1**	**10.00**	**0**	**0.00**	**2**	**6.67**
AU (n=10)	**4**	**40.00**	**3**	**30.00**	**2**	**20.00**	**9**	**30.00**
Total (n= 55)	**11**	**20.00**	**8**	**14.55**	**4**	**7.27**	**23**	**13.94**

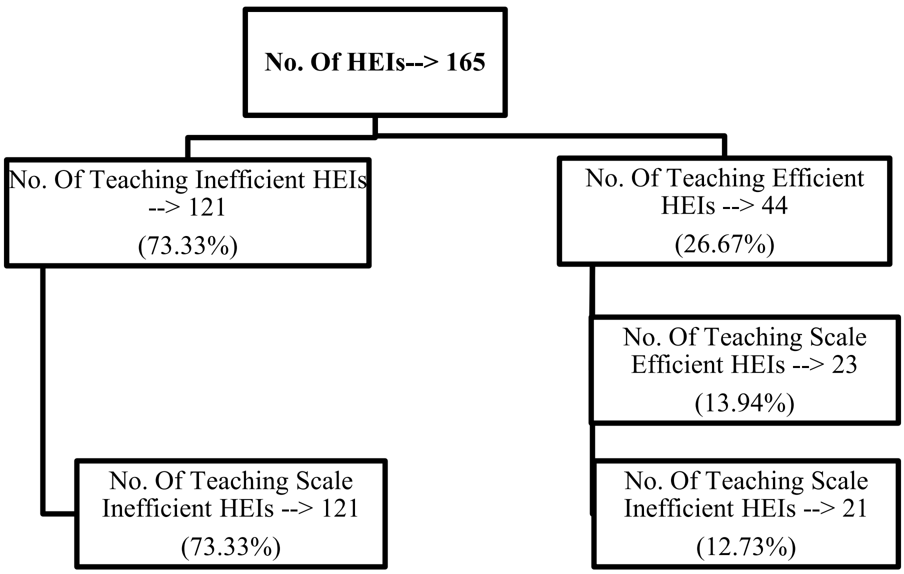


Figure 5.1 Number and Percentage of Teaching and Scale Efficient HEIs (2010-2012)

Table 5.10 Descriptive Statistic of Teaching Scale Efficiency Score by Year and HEIs' Type

Type	Statistic	2010	2011	2012	2010-2012
	Min.	0.3012	0.2474	0.2985	0.2474
	Max.	1.0000	1.0000	1.0000	1.0000
RB	**Mean**	**0.6212**	**0.6048**	**0.5489**	**0.5916**
	S.D.	0.2084	0.2160	0.1964	0.2070
	n	29.0000	29.0000	29.0000	87.0000
	Min.	0.5684	0.5807	0.2931	0.2931
	Max.	1.0000	0.7367	0.6858	1.0000
RM	**Mean**	**0.8122**	**0.6383**	**0.5245**	**0.6583**
	S.D.	0.2068	0.0553	0.1321	0.1828
	n	6.0000	6.0000	6.0000	18.0000
	Min.	0.4198	0.3326	0.3047	0.3047
	Max.	1.0000	1.0000	0.8056	1.0000
P	**Mean**	**0.6167**	**0.6433**	**0.5592**	**0.6064**
	S.D.	0.2035	0.1978	0.1605	0.1851
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.4028	0.4435	0.4602	0.4028
	Max.	1.0000	1.0000	1.0000	1.0000
AU	**Mean**	**0.8814**	**0.8221**	**0.8169**	**0.8401**
	S.D.	0.1829	0.2076	0.2020	0.1931
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.3012	0.2474	0.2931	0.2474
	Max.	1.0000	1.0000	1.0000	1.0000
Total	**Mean**	**0.6885**	**0.6550**	**0.5968**	**0.6468**
	S.D.	0.2257	0.2115	0.2092	0.2176
	n	55.0000	55.0000	55.0000	165.0000

Table 5.11 Number of HEIs' Teaching Return to Scale by Year and HEIs' Type

Type	2110			2011			2012			2010-2012		
	CRS	IRS	DRS	CRS	IRS	DRS	CRS	IRS	**DRS**	**CRS**	**IRS**	**DRS**
RB (n=29)	4.00	0.00	25.00	4.00	0.00	25.00	2.00	0.00	**27.00**	**10.00**	**0.00**	**77.00**
RM (n=6)	2.00	0.00	4.00	0.00	0.00	6.00	0.00	0.00	**6.00**	**2.00**	**0.00**	**16.00**
P (n=10)	1.00	0.00	9.00	1.00	0.00	9.00	0.00	0.00	**10.00**	**2.00**	**0.00**	**28.00**
AU (n=10)	4.00	0.00	6.00	3.00	0.00	7.00	2.00	0.00	**8.00**	**9.00**	**0.00**	**21.00**
Total (n= 55)	11.00	0.00	44.00	8.00	0.00	47.00	4.00	0.00	**51.00**	**23.00**	**0.00**	**142.00**

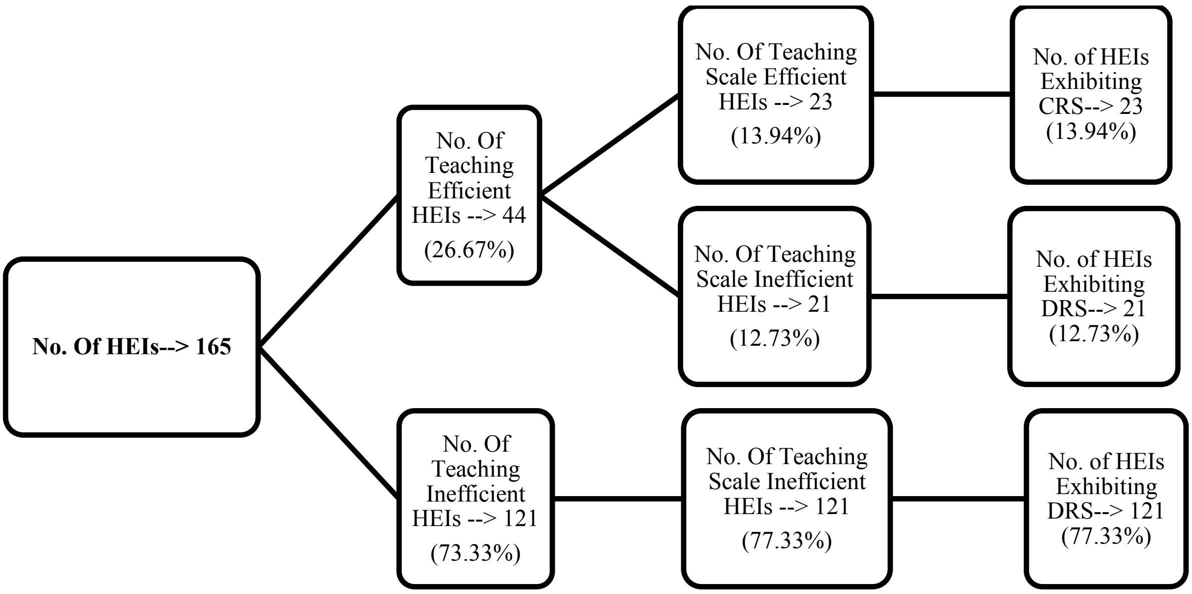


Figure 5.2 Number and Percentage of Teaching and Scale Efficient HEIs and Return to Scale in Teaching Production (2010-2012)

5.1.3 Research Efficiency of Thai Public Higher Education Institutions

5.1.3.1 Research Efficiency

The results of using DEA and double-bootstrap DEA for examining research efficiency of Thai public HEIs are reported in Table 5.12. The 1st column indicates HEIs name. The 2nd, 7th and 12th columns show the original research efficiency scores for the year 2010, 2011 and 2012, respectively. The bias-corrected research efficiency scores are revealed in the 3th, 8th and 13th columns. The corresponding bootstrap bias and the 95 % confidence interval for all HEIs over three years are presented in the next three columns. The original research efficiency scores are used in the first stage of analysis to examine the research efficiency during 2010-2012 while the bias-corrected research efficiency scores are employed in the second stage to investigate the effects of public funding for HE on HEIs research efficiency.

As regard to the original research efficiency score, the results suggest that the majority of Thai public HEIs is research inefficiency. Since there exist only 36.36 percent of them being research efficiency (Table 5.13). The percentages of research efficient HEIs vary from 34.55 to 40.00 during 2010-2012.

Comparing the number of research efficient HEIs across HEIs' types, the results as shown in Table 5.13 reveal that autonomous university has the largest share of 60.00%, followed by Rajamangaly University of Technology of 44.44 %. In contrast, public university has the lowest share of 20.00 %.

Regarding the descriptive statistics of research efficiency scores, Table 5.14 shows that, on average of three years, the score is 0.7467 and its value fluctuates from 0.0861 to 1.000 with 0.2561 standard deviation. This implies that research inefficient HEIs could increase the producing of outputs (given level of inputs) by 33.92 percent to be research efficient HEIs. Moreover, the average score of each year is slightly stable in three years.

With regard to HEIs types, autonomous university has the highest level of average research efficiency score (0.8835), followed by public university (0.7485). As the type with the highest research efficiency score, it is worthy to scrutinize the relative position of their inputs and outputs. Despite their weaker performance on the inputs side such as number of academic staffs holding assistance professor or higher (ACASTWAP), number of graduate students (GST), and number of non-academic staff (NACST), autonomous university has the highest level of many outputs such academic staff's publication index (ACSTPID), ratio of publication numbers to academic staff numbers (PNPACST), percentage of academic staff's research article published in category 4 (PERACSTR4), and percentage of graduate student's research article published in category 4 (PERGSTR4) (Table 5.4). In contrast, Rajabhat University has the lowest average research efficiency score (0.7003), since they produce the relative lowest level of all outputs (Table 5.4). As a result, it would be possible for Rajabhat University to become research efficient HEIs by increasing their outputs level, given inputs level, around 42.82 %.

5.1.3.2 Research Scale Efficiency

The results of examining the research scale efficiency of Thai public HEIs, by solving DEA-CCR and DEA-BBC research efficiency model, as mentioned in section 4.1.4.2, are revealed in Table 5.15. By solving the two models, two efficiency scores are obtained: research overall efficiency and research pure efficiency, respectively. The ratio of the two efficiency scores serves as a measure of research scale efficiency. Remembrance that HEIs with research scale efficiency score equal to 1 is considered to be research scale efficient HEIs while the ones with research scale efficiency score less than 1 is deemed to be relatively scale inefficient HEIs.

The results of examining the research scale efficiency of Thai public HEIs are revealed in Table 5.15. From the table, it is evidently seen that the majority of them are research scale inefficiency. Over three year, only 47 from 165, accounted for 28.48 %, are research scale efficient HEIs. Over time, this percentage increases in every year from 34.55 % in 2010 to 40.00 % in 2012. Moreover, all of them are also research efficient HEIs. Alternatively, research scale inefficient HEIs (including 118 HEIs) composes of 2 kinds: 13 research efficient and 105 research inefficient HEIs (see Figure 5.3). The 13 HEIs, accounted for 7.88 %, operate on the research production frontier but cannot attain the highest productivity while the 105, accounted for 63.64 %, are unable to operate on the efficient frontier and achieve the highest productivity.

Concerning HEIs' Type, the results in Table 5.16 reveals that autonomous university has the largest share of research scale efficient HEIs, its share over the three years is about 60.00 %. On the other hand, public university has the lowest with only 20.00 % share.

Regarding research scale efficiency score, the average score, as presented in Table 5.17, is rather high (0.9352). Moreover, it is higher than the average research efficiency score (0.7467) (see Table 5.14 and 5.17). This implies that research inefficiency of Thai public HEIs is mainly caused by the ability to manage their resources for producing research but not the scale of production. In order to become more research efficiency, these HEIs require to increase their production of research outputs (given the inputs level) by 33.92 % and to adjust their scale of production (given the same mix of inputs and outputs) by 6.93 %.

Comparing across HEI types, the findings also reveal that, autonomous university has the highest level of average research scale efficiency scores (0.9855), followed by public university (0.9812). In contrast, Rajabhat University has the lowest level (0.8995). Their average of research scale efficiency score is lower than of research efficiency score (0.7033). This implies that research inefficiency of Rajabhat University is mainly driven by inefficiency of using research inputs to produce research outputs. Therefore, to reach the efficiency frontier at the highest level of productivity, they are obliged to expand their research outputs (given the inputs level) by 42.19.46 % and to alter their production scale (given the same mix of inputs and outputs) only by 11.17 %.

5.1.3.3 Return to Scale of Research Production

Although research inefficiency of Thai public HEIs slightly relates to scale of production. It is still reasonable to examine sources of research scale inefficiency by identifying returns to scale in producing research.

In order to identify the returns to scale, Färe and Grosskopf (1985)'s scale efficiency index is employed. The empirical findings, presented in Table 5.18 and Figure 5.4, clearly indicate that the majority of the public HEIs tend to operate at IRS in producing research. Each year, there exists around 50.00 % of HEIs operate at IRS while the remaining of HEIs, around 30% and 20%, operate at CRS and DRS, respectively. This implies that a half of Thai public HEIs in the sample set are deemed to be operated below an optimal scale and so could increase their level of productivity by expanding the size of operation. Those exhibiting DRS might decrease their productivity through reduction below their current scale of production.

Table 5.18 also describes the nature of return to scale of HEIs across HEIS types. From the Table, it is obviously seen that, over three years, the majority of Rajabhat University, Rajamangala University of Technology, and public university (accounted for 55.77 %, 55.56 %, and 46.67 % respectively), operate at IRS. On the other hand, the large parts of autonomous university (accounted for 55.67 %) operate at CRS.

Table 5.12 Research Efficiency Score by Year and HEIs' Type

HEIs	2010					2011					2012				
	Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
Ku	0.6954	0.5920	0.1034	0.5303	0.6599	0.7132	0.6143	0.0989	0.5506	0.6784	1.0000	0.7807	0.2193	0.6454	0.9135
KKU	1.0000	0.8024	0.1976	0.6769	1.0407	0.8108	0.7175	0.0934	0.6446	0.8122	1.0000	0.8499	0.1501	0.7487	1.0577
TU	0.6247	0.5643	0.0604	0.5198	0.6118	0.6282	0.5671	0.0611	0.5250	0.6150	0.7175	0.6177	0.0998	0.5525	0.7069
NU	0.7173	0.6394	0.0780	0.5837	0.6869	0.7531	0.6707	0.0824	0.6085	0.7402	0.9485	0.8384	0.1101	0.7608	0.9143
MSU	1.0000	0.7860	0.2140	0.6508	1.0435	0.6454	0.5442	0.1012	0.4735	0.6941	0.8802	0.7598	0.1204	0.6709	0.9141
MJU	0.3214	0.2757	0.0457	0.2471	0.3094	0.5237	0.4665	0.0572	0.4236	0.5198	0.7070	0.6142	0.0927	0.5509	0.6881
SWU	0.6229	0.5575	0.0654	0.5106	0.6016	0.9353	0.8455	0.0898	0.7795	0.9103	0.5039	0.4602	0.0437	0.4269	0.4932
SU	0.5002	0.4357	0.0645	0.3913	0.4867	0.5506	0.4905	0.0602	0.4472	0.5439	0.6277	0.5594	0.0683	0.5107	0.6226
PSU	0.9393	0.8532	0.0861	0.7942	0.9147	0.8977	0.8095	0.0882	0.7419	0.8831	1.0000	0.8999	0.1001	0.8295	0.9979
UBU	0.5146	0.4439	0.0708	0.3974	0.5041	1.0000	0.7912	0.2088	0.6636	1.1288	0.6769	0.5999	0.0769	0.5449	0.6505
KRU	1.0000	0.7148	0.2852	0.5589	0.9858	1.0000	0.7338	0.2662	0.5860	0.9347	1.0000	0.7361	0.2639	0.5910	1.0088
KPRU	0.4269	0.3397	0.0872	0.2917	0.3982	0.7547	0.6074	0.1473	0.5190	0.7705	0.6358	0.4864	0.1494	0.4131	0.6012
CHANDRA	0.5233	0.4507	0.0726	0.4052	0.4955	0.3617	0.2897	0.0720	0.2494	0.3438	0.4188	0.3375	0.0813	0.2928	0.3926
CRRU	0.0861	0.0693	0.0168	0.0598	0.0767	0.1816	0.1468	0.0348	0.1249	0.1709	0.2586	0.2081	0.0505	0.1811	0.2260
CMRU	0.4337	0.3633	0.0704	0.3228	0.4279	0.4325	0.3561	0.0764	0.3056	0.4049	1.0000	0.7944	0.2056	0.6749	0.9111
NPRU	0.9481	0.7809	0.1673	0.6677	1.0093	1.0000	0.7193	0.2807	0.5723	0.9511	1.0000	0.6963	0.3037	0.5595	0.8865
LPRU	1.0000	0.7555	0.2445	0.6161	1.0206	1.0000	0.7387	0.2613	0.5969	1.0579	1.0000	0.7262	0.2738	0.5786	0.9581
NRRU	0.2524	0.2112	0.0412	0.1872	0.2369	0.5095	0.4319	0.0776	0.3874	0.4938	0.4251	0.3489	0.0762	0.3076	0.3839
NSTRU	0.9247	0.7229	0.2018	0.6199	0.8661	1.0000	0.7426	0.2574	0.5960	1.0276	1.0000	0.7098	0.2902	0.5637	0.9308
NSRU	0.4283	0.3554	0.0729	0.3088	0.4095	0.4958	0.4190	0.0768	0.3688	0.4777	0.4035	0.3283	0.0753	0.2827	0.3743
BSRU	0.4283	0.3388	0.0894	0.2845	0.3844	0.6019	0.5013	0.1006	0.4389	0.5568	0.3393	0.2605	0.0787	0.2167	0.3022

Table 5.12 (Continued)

HEIs	2010					2011					2012				
	Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
BRU	0.4321	0.3480	0.0841	0.3046	0.4008	0.6526	0.5495	0.1031	0.4831	0.6399	1.0000	0.7727	0.2273	0.6616	0.8480
PNRU	0.5434	0.4425	0.1009	0.3754	0.5168	0.3951	0.3254	0.0697	0.2870	0.3614	0.3845	0.3200	0.0645	0.2761	0.3570
ARU	1.0000	0.8268	0.1732	0.7297	0.9331	1.0000	0.7597	0.2403	0.6195	1.1152	0.6902	0.5737	0.1165	0.4969	0.6728
PSRU	0.9501	0.7791	0.1710	0.6753	0.9157	0.9582	0.7756	0.1826	0.6611	0.8920	1.0000	0.7245	0.2755	0.5762	1.0082
PBRU	0.9805	0.7790	0.2014	0.6491	0.9330	0.5616	0.4721	0.0895	0.4185	0.5195	1.0000	0.7264	0.2736	0.5860	0.8687
PCRU	0.4972	0.4043	0.0929	0.3552	0.4455	1.0000	0.7576	0.2424	0.6150	0.9231	1.0000	0.6761	0.3239	0.5245	0.8751
PKRU	0.6532	0.5161	0.1371	0.4357	0.5955	0.6967	0.5540	0.1428	0.4670	0.6249	0.8038	0.6447	0.1591	0.5571	0.7351
RMU	0.9213	0.7749	0.1464	0.6772	0.9387	0.8713	0.7240	0.1474	0.6373	0.8798	0.8745	0.7128	0.1617	0.6106	0.8820
YRU	0.2532	0.2027	0.0504	0.1726	0.2404	0.2645	0.2152	0.0493	0.1832	0.2435	1.0000	0.7349	0.2651	0.5910	1.0515
LRU	0.3615	0.2826	0.0790	0.2393	0.3177	1.0000	0.7921	0.2079	0.6742	0.9190	0.6023	0.4924	0.1099	0.4244	0.5616
VRU	0.4608	0.3954	0.0654	0.3517	0.4299	0.5178	0.4329	0.0848	0.3840	0.4807	0.3204	0.2710	0.0494	0.2381	0.2990
SSKRU	1.0000	0.6596	0.3404	0.5014	0.8623	1.0000	0.6695	0.3305	0.5197	0.8651	1.0000	0.6881	0.3119	0.5290	0.8734
SKRU	1.0000	0.7012	0.2988	0.5483	0.9052	0.6168	0.5058	0.1110	0.4350	0.6129	0.5321	0.4151	0.1170	0.3469	0.5207
DUSIT	0.3344	0.2917	0.0427	0.2673	0.3196	1.0000	0.7234	0.2766	0.5745	1.0057	1.0000	0.7319	0.2681	0.5968	1.0334
SSRU	0.7469	0.6103	0.1366	0.5301	0.6834	0.2915	0.2455	0.0460	0.2144	0.2947	0.6648	0.5487	0.1161	0.4975	0.6060
MCRU	1.0000	0.7535	0.2465	0.6168	1.0324	0.6207	0.5256	0.0951	0.4656	0.5983	0.9461	0.7751	0.1709	0.6606	0.8925
URU	0.7618	0.6459	0.1158	0.5657	0.7332	1.0000	0.8165	0.1835	0.6951	0.9191	0.9694	0.7972	0.1722	0.6948	0.9013
UBRU	0.7561	0.6543	0.1018	0.5926	0.7512	0.5589	0.4862	0.0727	0.4409	0.5797	0.4704	0.3874	0.0831	0.3356	0.4335
RMUTT	0.4096	0.3405	0.0691	0.2943	0.3841	0.3368	0.2952	0.0416	0.2652	0.3310	0.7158	0.6040	0.1118	0.5360	0.6618
RMUTK	1.0000	0.6461	0.3539	0.4895	0.7984	1.0000	0.6848	0.3152	0.5295	0.8839	1.0000	0.6712	0.3288	0.5095	0.8673

Table 5.12 (Continued)

HEIs	2010					2011					2012				
	Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score				Original Research Efficiency Score	Bootstrapped Research Efficiency Score			
		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound		Bias-corrected Score	Bias	Lower Bound	Upper Bound
RMUTP	1.0000	0.7078	0.2922	0.5561	0.8779	0.2956	0.2540	0.0415	0.2248	0.2842	0.4200	0.3594	0.0606	0.3185	0.4057
RMUTSB	1.0000	0.7551	0.2449	0.6319	0.8988	1.0000	0.7407	0.2593	0.5983	1.0648	0.5688	0.4595	0.1093	0.3969	0.5191
RMUTR	1.0000	0.7341	0.2659	0.5928	1.0156	0.4786	0.3878	0.0908	0.3297	0.4502	0.5332	0.4332	0.1000	0.3811	0.5109
RMUTI	1.0000	0.8024	0.1976	0.6898	0.8883	0.5829	0.4729	0.1101	0.4132	0.5329	0.7134	0.5932	0.1202	0.5211	0.6738
CHULA	1.0000	0.8327	0.1673	0.7204	1.0208	1.0000	0.8133	0.1867	0.6934	1.0591	1.0000	0.8833	0.1167	0.8034	1.0163
CMU	1.0000	0.8466	0.1534	0.7371	1.0539	1.0000	0.8228	0.1772	0.7181	1.1098	1.0000	0.8881	0.1119	0.8037	0.9869
TSU	0.8584	0.7329	0.1255	0.6453	0.8356	0.5422	0.4648	0.0774	0.4132	0.5418	0.5888	0.5020	0.0869	0.4465	0.5851
KMITT	0.9344	0.8106	0.1238	0.7190	0.9152	1.0000	0.8603	0.1397	0.7635	1.0069	1.0000	0.8370	0.1630	0.7273	0.9581
KMITNB	1.0000	0.7873	0.2127	0.6546	1.0662	0.8776	0.7641	0.1135	0.6843	0.8434	0.8406	0.7361	0.1045	0.6636	0.8443
SUT	1.0000	0.8767	0.1233	0.7857	1.0317	1.0000	0.8371	0.1629	0.7249	1.0927	1.0000	0.8419	0.1581	0.7325	1.0825
BUU	0.4289	0.3712	0.0577	0.3304	0.4198	0.4012	0.3549	0.0464	0.3207	0.3914	0.7010	0.6152	0.0859	0.5536	0.6801
MAHIDOL	1.0000	0.8161	0.1839	0.6962	1.1028	1.0000	0.8432	0.1568	0.7399	1.1011	1.0000	0.8199	0.1801	0.6994	1.0473
WU	1.0000	0.8274	0.1726	0.7125	1.1363	1.0000	0.8327	0.1673	0.7256	1.1229	1.0000	0.7984	0.2016	0.6702	1.0479
KMITL	0.5708	0.4843	0.0866	0.4326	0.5458	0.7838	0.6961	0.0877	0.6348	0.7830	0.9786	0.8465	0.1322	0.7537	0.9660

Table 5.13 Number and Percentage of Research Efficient HEIs by Year and HEIs' Type

Type	2010		2011		2012		2010-2012 (n =165)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
RB (n=29)	6.00	20.69	10.00	34.48	12.00	41.38	28.00	32.18
RM (n=6)	5.00	83.33	2.00	33.33	1.00	16.67	8.00	44.44
P (n=10)	2.00	20.00	1.00	10.00	3.00	30.00	6.00	20.00
AU (n=10)	6.00	60.00	6.00	60.00	6.00	60.00	18.00	60.00
Total (n= 55)	19.00	34.55	19.00	34.55	22.00	40.00	60.00	36.36

Table 5.14 Descriptive Statistics of Research Efficiency Scores by Year and HEIs' Type

Type	Statistic	2010	2011	2012	2010-2012
	Min.	0.0861	0.1816	0.2586	0.0861
	Max.	1.0000	1.0000	1.0000	1.0000
RB	**Mean**	**0.6588**	**0.7015**	**0.7496**	**0.7033**
	S.D.	0.2896	0.2725	0.2732	0.2778
	n	29.0000	29.0000	29.0000	87.0000
	Min.	0.4096	0.2956	0.4200	0.2956
	Max.	1.0000	1.0000	1.0000	1.0000
RM	**Mean**	**0.9016**	**0.6157**	**0.6585**	**0.7253**
	S.D.	0.2410	0.3148	0.2018	0.2739
	n	6.0000	6.0000	6.0000	18.0000
	Min.	0.3214	0.5237	0.5039	0.3214
	Max.	1.0000	1.0000	1.0000	1.0000
P	**Mean**	**0.6936**	**0.7458**	**0.8062**	**0.7485**
	S.D.	0.2276	0.1634	0.1814	0.1917
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.4289	0.4012	0.5888	0.4012
	Max.	1.0000	1.0000	1.0000	1.0000
AU	**Mean**	**0.8793**	**0.8605**	**0.9109**	**0.8835**
	S.D.	0.2079	0.2199	0.1509	0.1896
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.0861	0.1816	0.2586	0.0861
	Max.	1.0000	1.0000	1.0000	1.0000
Total	**Mean**	**0.7317**	**0.7291**	**0.7793**	**0.7467**
	S.D.	0.2740	0.2555	0.2391	0.2561
	n	55.0000	55.0000	55.0000	165.0000

Table 5.15 Research Scale Efficiency and HEIs' Return to Scale of Research Production

HEIs	2010				2011				2012			
	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS
KU	0.6544	0.6954	0.9410	DRS	0.6879	0.7132	0.9644	DRS	1.0000	1.0000	1.0000	CRS
KKU	1.0000	1.0000	1.0000	CRS	0.8103	0.8108	0.9994	IRS	1.0000	1.0000	1.0000	CRS
TU	0.6067	0.6247	0.9712	DRS	0.6004	0.6282	0.9558	DRS	0.7104	0.7175	0.9901	DRS
NU	0.6528	0.7173	0.9100	IRS	0.7496	0.7531	0.9954	IRS	0.8482	0.9485	0.8942	IRS
MSU	1.0000	1.0000	1.0000	CRS	0.6362	0.6454	0.9857	DRS	0.8680	0.8802	0.9861	DRS
MJU	0.3150	0.3214	0.9800	DRS	0.5180	0.5237	0.9890	DRS	0.6901	0.7070	0.9761	DRS
SWU	0.6078	0.6229	0.9757	IRS	0.9269	0.9353	0.9911	IRS	0.4985	0.5039	0.9893	IRS
SU	0.4985	0.5002	0.9966	IRS	0.5434	0.5506	0.9868	IRS	0.6143	0.6277	0.9786	IRS
PSU	0.9375	0.9393	0.9980	IRS	0.8976	0.8977	0.9998	IRS	1.0000	1.0000	1.0000	CRS
UBU	0.5073	0.5146	0.9857	IRS	1.0000	1.0000	1.0000	CRS	0.6748	0.6769	0.9969	IRS
KRU	1.0000	1.0000	1.0000	CRS	0.4900	1.0000	0.4900	IRS	0.6476	1.0000	0.6476	IRS
KPRU	0.4207	0.4269	0.9856	DRS	0.4481	0.7547	0.5938	IRS	0.5973	0.6358	0.9395	DRS
CHANDRA	0.4562	0.5233	0.8718	IRS	0.3301	0.3617	0.9125	DRS	0.4135	0.4188	0.9874	DRS
CRRU	0.0839	0.0861	0.9750	IRS	0.1774	0.1816	0.9769	DRS	0.2565	0.2586	0.9918	DRS
CMRU	0.4324	0.4337	0.9971	IRS	0.4323	0.4325	0.9996	DRS	1.0000	1.0000	1.0000	CRS
NPRU	0.8159	0.9481	0.8606	IRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
LPRU	1.0000	1.0000	1.0000	CRS	0.8329	1.0000	0.8329	IRS	1.0000	1.0000	1.0000	CRS
NRRU	0.2493	0.2524	0.9876	IRS	0.4230	0.5095	0.8303	DRS	0.4200	0.4251	0.9879	DRS
NSTRU	0.6834	0.9247	0.7391	IRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
NSRU	0.4050	0.4283	0.9457	IRS	0.4500	0.4958	0.9076	IRS	0.4031	0.4035	0.9989	IRS
BSRU	0.4090	0.4283	0.9550	IRS	0.5461	0.6019	0.9072	IRS	0.3319	0.3393	0.9782	IRS
BRU	0.4313	0.4321	0.9980	IRS	0.6524	0.6526	0.9997	DRS	1.0000	1.0000	1.0000	CRS

Table 5.15 (Continued)

HEIs	2010				2011				2012			
	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS
PNRU	0.5371	0.5434	0.9884	DRS	0.3516	0.3951	0.8900	DRS	0.3736	0.3845	0.9716	IRS
ARU	0.6389	1.0000	0.6389	IRS	1.0000	1.0000	1.0000	CRS	0.5679	0.6902	0.8229	IRS
PSRU	0.9328	0.9501	0.9819	DRS	0.9523	0.9582	0.9938	DRS	1.0000	1.0000	1.0000	CRS
PBRU	0.9206	0.9805	0.9390	IRS	0.4827	0.5616	0.8595	IRS	1.0000	1.0000	1.0000	CRS
PCRU	0.4032	0.4972	0.8109	IRS	0.5336	1.0000	0.5336	IRS	0.3710	1.0000	0.3710	IRS
PKRU	0.5507	0.6532	0.8432	IRS	0.5226	0.6967	0.7501	IRS	0.7567	0.8038	0.9415	IRS
RMU	0.8118	0.9213	0.8811	IRS	0.7758	0.8713	0.8904	IRS	0.8698	0.8745	0.9947	IRS
YRU	0.1853	0.2532	0.7318	IRS	0.2034	0.2645	0.7690	IRS	0.9041	1.0000	0.9041	IRS
LRU	0.3568	0.3615	0.9870	IRS	0.6114	1.0000	0.6114	IRS	0.5346	0.6023	0.8877	IRS
VRU	0.4014	0.4608	0.8712	IRS	0.5138	0.5178	0.9923	IRS	0.2817	0.3204	0.8792	IRS
SSKRU	1.0000	1.0000	1.0000	CRS	0.6026	1.0000	0.6026	IRS	1.0000	1.0000	1.0000	CRS
SKRU	1.0000	1.0000	1.0000	CRS	0.5994	0.6168	0.9719	IRS	0.4905	0.5321	0.9218	IRS
DUSIT	0.3334	0.3344	0.9970	DRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
SSRU	0.7376	0.7469	0.9876	DRS	0.2792	0.2915	0.9579	IRS	0.6634	0.6648	0.9979	IRS
MCRU	1.0000	1.0000	1.0000	CRS	0.5379	0.6207	0.8665	IRS	0.7153	0.9461	0.7561	IRS
URU	0.6974	0.7618	0.9155	IRS	0.8497	1.0000	0.8497	IRS	0.7203	0.9694	0.7431	IRS
UBRU	0.6544	0.7561	0.8655	IRS	0.4639	0.5589	0.8300	IRS	0.4528	0.4704	0.9625	DRS
RMUTT	0.3993	0.4096	0.9749	IRS	0.3332	0.3368	0.9894	IRS	0.7158	0.7158	1.0000	IRS
RMUTK	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
RMUTP	0.6342	1.0000	0.6342	IRS	0.2907	0.2956	0.9835	IRS	0.4195	0.4200	0.9990	IRS
RMUTSB	0.6299	1.0000	0.6299	IRS	1.0000	1.0000	1.0000	CRS	0.5361	0.5688	0.9425	IRS
RMUTR	1.0000	1.0000	1.0000	CRS	0.4650	0.4786	0.9715	IRS	0.5109	0.5332	0.9581	IRS

Table 5.15 (Continued)

HEIs	2010				2011				2012			
	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS	Research Overall Efficiency (DEA-CCR model)	Research Pure Efficiency (DEA-BCC model)	Research Scale Efficiency	RTS
RMUTI	1.0000	1.0000	1.0000	CRS	0.5800	0.5829	0.9950	DRS	0.6956	0.7134	0.9750	DRS
CHULA	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	0.9977	1.0000	0.9977	IRS
CMU	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
TSU	0.8174	0.8584	0.9522	IRS	0.4903	0.5422	0.9043	DRS	0.5174	0.5888	0.8787	DRS
KMITT	0.9231	0.9344	0.9879	IRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
KMITNB	1.0000	1.0000	1.0000	CRS	0.8774	0.8776	0.9998	DRS	0.8403	0.8406	0.9996	IRS
SUT	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
BUU	0.4201	0.4289	0.9794	DRS	0.3839	0.4012	0.9567	IRS	0.6451	0.7010	0.9202	IRS
MAHIDOL	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
WU	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS	1.0000	1.0000	1.0000	CRS
KMITL	0.5679	0.5708	0.9950	DRS	0.7829	0.7838	0.9989	IRS	0.9734	0.9786	0.9946	IRS

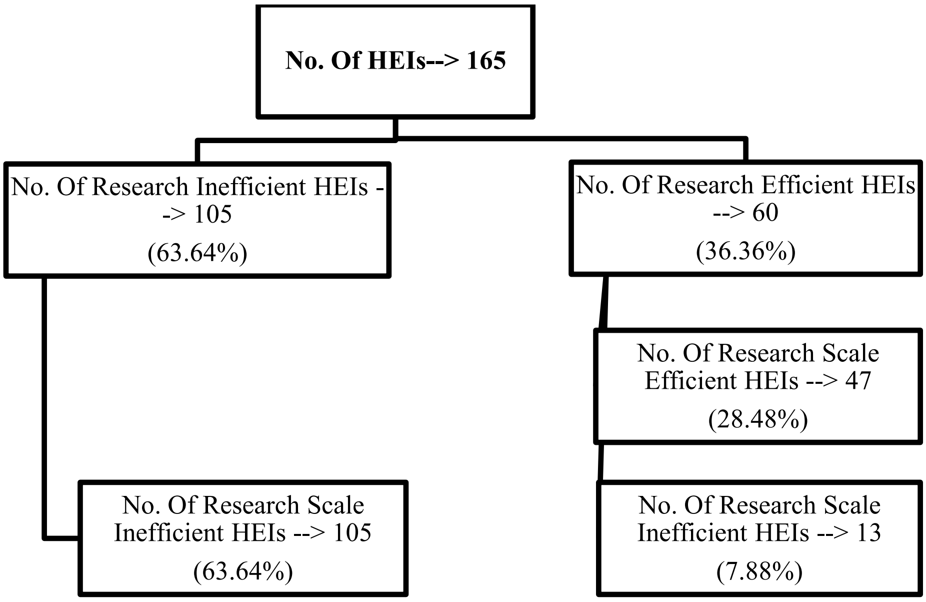


Figure 5.3 Number and Percentage of Research and Research Scale Efficient HEIs (2010-2012)

Table 5.16 Number and Percentage of Research Scale Efficient HEIs by Year and HEIs' Type

Type	2010		2011		2012		2010-2012 (n =165)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
RB (n=29)	5	17.24	4	13.79	9	31.03	18	32.18
RM (n=6)	3	50.00	2	33.33	1	16.67	6	44.44
P (n=10)	2	20.00	1	10.00	3	30.00	6	20.00
AU (n=10)	6	60.00	6	60.00	5	50.00	17	60.00
Total (n= 55)	16	29.09	13	23.64	18	32.73	47	36.36

Table 5.17 Descriptive Statistic of Research Scale Efficiency Score by Year and HEIs' Type

Type	Statistic	2010	2011	2012	2010-2012
	Min.	0.6389	0.4900	0.3710	0.3710
	Max.	1.0000	1.0000	1.0000	1.0000
RB	**Mean**	**0.9226**	**0.8558**	**0.9202**	**0.8995**
	S.D.	0.0962	0.1538	0.1395	0.1342
	n	29.0000	29.0000	29.0000	87.0000
	Min.	0.6299	0.9715	0.9425	0.6299
	Max.	1.0000	1.0000	1.0000	1.0000
RM	**Mean**	**0.8732**	**0.9899**	**0.9791**	**0.9474**
	S.D.	0.1870	0.0110	0.0248	0.1159
	n	6.0000	6.0000	6.0000	18.0000
	Min.	0.9100	0.9558	0.8942	0.8942
	Max.	1.0000	1.0000	1.0000	1.0000
P	**Mean**	**0.9758**	**0.9867**	**0.9811**	**0.9812**
	S.D.	0.0294	0.0151	0.0318	0.0259
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.9522	0.9043	0.8787	0.8787
	Max.	1.0000	1.0000	1.0000	1.0000
AU	**Mean**	**0.9915**	**0.9860**	**0.9791**	**0.9855**
	S.D.	0.0154	0.0317	0.0431	0.0315
	n	10.0000	10.0000	10.0000	30.0000
	Min.	0.6299	0.4900	0.3710	0.3710
	Max.	1.0000	1.0000	1.0000	1.0000
Total	**Mean**	**0.9394**	**0.9179**	**0.9484**	**0.9352**
	S.D.	0.0980	0.1299	0.1074	0.1126
	n	55.0000	55.0000	55.0000	165.0000

Table 5.18 HEIs' Research Return to Scale by Year, HEIs' Type

Type	2110			2011			2012			2010-2012		
	CRS	IRS	DRS	CRS	IRS	DRS	CRS	IRS	DRS	CRS	IRS	DRS
RB (n=29)	5	19	5	4	18	7	9	15	5	18	52	17
RM (n=6)	3	3	0	2	3	1	1	4	1	6	10	2
P (n=10)	2	5	3	1	5	4	3	4	3	6	14	10
AU (n=10)	6	2	2	6	2	2	5	4	1	17	8	5
Total (n= 55)	16	29	10	13	28	14	18	27	10	47	84	34

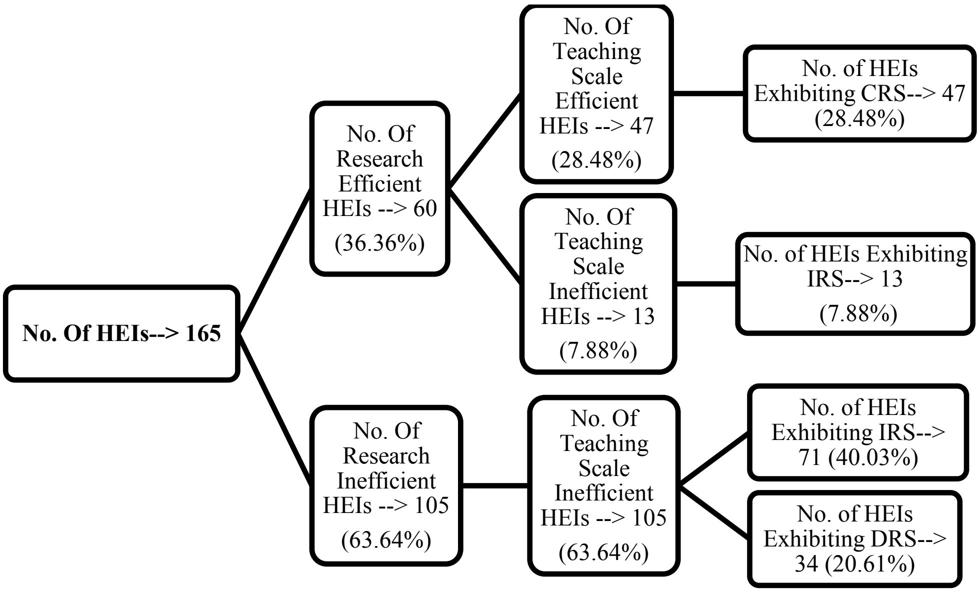


Figure 5.4 Number and Percentage of Research and Scale Efficient HEIs and Return to Scale in Research Production (2010-2012)

5.1.4 Effects of Public Funding for Higher Education on Higher Education Institutions Efficiency

The objectives of this study is not only to measure efficiency of Thai public HEIs but also to scrutinize how public funding for HE system affects the teaching and research efficiency. Therefore, the second step of analysis is conducted by treating the teaching and research technical efficiency scores as dependent variable in regression equation 4.10 (Teaching Model) and 4.11 (Research Model) as shown in Chapter 4.

However, since the DEA efficiency scores estimated in the first stage are left truncated at zero and limited between 0 and 1, estimation via ordinary least squares (OLS) would result in inconsistent estimates. Generally, in the DEA standard methods for estimating what determines the efficiency, Tobit-estimator has mainly been applied. However, the possible statistical problems stemming from applying Tobit regression, such as DEA efficiency scores are not observed but estimated and by construction serially correlated, inputs and outputs can be correlated with environmental factors, might occur since the efficiency scores are truncated by construction and not because of censoring. Thus, a truncated maximum likelihood regression would be appropriate than a Tobit regression.

Therefore, in order to ensure the statistical accuracy of the analysis and to consistently estimate the parameters with valid confidence intervals, this study applies a double bootstrap procedure for two-stage approach, based on the procedure of Simar and Wilson (2007), as previously detailed in chapter 4. According to Simar and Wilson (2007), DEA efficiency scores are bootstrapped in the first stage to achieve bias corrected inefficiency scores and; then, in the second stage of analysing the dependency of the efficiency on a set of environmental factors, a consistent bootstrap-truncated regression to consistently estimate the parameters using maximum likelihood estimation is employed. Since the value of bias-corrected DEA teaching and research efficiency scores, as dependent variable in model 4.10 and 4.11, are in the interval (0, 1), this implies that a positive sign of estimated regression's coefficients indicates that, ceteris paribus, an increase in independent variable corresponds to higher efficiency while a negative sign of estimated regression' s coefficients indicates lower efficiency. To provide the evidence on the relationship between HEIs' efficiency and set of environment factors, the teaching model (4.10) and research model (4.11) are estimated with the following specification in the second stage truncated regression analysis:

Teaching Model:

$$BTEFFSC_{jt} = \beta_0 + \beta_1 PFPFTES_{jt} + \beta_2 PERPF_{jt} + \beta_3 PERINEX_{jt} + \beta_4 GRP_{jt} + \beta_5 MED_j + \beta_6 AGEF_{jt} + \beta_7 IQA\_ASSC_{jt} + \beta_8 RM.U_j + \beta_9 PB.U_j + \beta_{10} AUTO.U_j + \varepsilon_{jt} \quad (4.10)$$

Research Model:

$$BREFFSC_{jt} = \beta_0 + \beta_1 PFPFTES_{jt} + \beta_2 PERPF_{jt} + \beta_3 PERINEX_{jt} + \beta_4 GRP_{jt} + \beta_5 MED_j + \beta_6 AGEF_{jt} + \beta_7 IQA\_ASSC_{jt} + \beta_8 RM.U_j + \beta_9 PB.U_j + \beta_{10} AUTO.U_j + \varepsilon_{jt} \quad (4.11)$$

The choice of environment variables employed in the study has already been presented in chapter 4. Table 5.19 demonstrates the descriptive statistics of environment variables used in the second stage analysis on teaching and research model.

Table 5.19 Descriptive Statistics of Environmental Variables at Second Stage Analysis on Teaching and Research Model by HEIs type

Type	**Statistics**	**PFPFTES**	**PERPF**	**PERINEX**	**GRP**	**IQA_ASSC**	**AGEF**
	Min	1.89	0.27	0.01	11.74	2.24	2.83
	Max	2.61	0.91	0.57	29.09	4.57	4.82
RB	Mean	2.18	0.59	0.21	27.26	3.96	4.20
	S.D.	0.18	0.12	0.10	1.86	0.45	0.43
	n	87.00	87.00	87.00	87.00	87.00	87.00
	Min	1.95	0.66	0.10	26.95	3.11	3.66
	Max	2.45	0.85	0.41	29.09	4.50	4.74
RM	Mean	2.21	0.77	0.23	27.75	3.96	4.28
	S.D.	0.15	0.05	0.08	0.95	0.34	0.36
	n	18.00	18.00	18.00	18.00	18.00	18.00
	Min	1.91	0.25	0.04	27.07	2.06	3.26
	Max	2.44	0.67	0.29	29.09	4.72	4.78
P	Mean	2.15	0.44	0.14	27.99	4.01	4.12
	S.D.	0.13	0.10	0.07	0.88	0.60	0.42
	n	30.00	30.00	30.00	30.00	30.00	30.00
	Min	1.95	0.25	0.00	26.95	1.96	3.09
	Max	2.58	0.75	0.33	29.09	4.81	4.84
AU	Mean	2.23	0.50	0.10	28.03	3.86	3.99
	S.D.	0.15	0.16	0.10	0.88	0.81	0.52
	n	30.00	30.00	30.00	30.00	30.00	30.00
	Min	1.89	0.25	0.00	11.74	1.96	2.83
	Max	2.61	0.91	0.57	29.09	4.81	4.84
Total	Mean	2.19	0.56	0.18	27.59	3.95	4.16
	S.D.	0.16	0.15	0.11	1.52	0.55	0.44
	n	165.00	165.00	165.00	165.00	165.00	165.00

The results of estimation by using the second-stage truncated regression analysis are presented in Table 5.20 and 5.21. From the two tables, it is clearly seen that, overall, both models (teaching and research model) perform well. Most estimated coefficients are statistically significant at 0.01 significant levels. Moreover, 7 out of 10 independent variables carry the same sign in both teaching and research models but slightly differences in the magnitude of coefficients. Those variables are: ratio of public funding to FTEs student (PFPFTES); percentage of HEIs' investment expenditure in HEIs' expenditure (PERINEX); value of Gross Regional Product per Capita (GRP); internal quality score from Self-Assessment Report (IQA_ASSC); Age of HEIs (AGEF); dummy variable for Public University (PBU); and dummy variable for Autonomous University (AUTOU).

The results in Table 5.20 and 5.21 also reveal that all variables in the group of public funding have a significant effect on teaching and research technical efficiency of Thai public HEIs. The ratio of public funding to FTEs student (PFPFTES), in log value, has a positively and statistically significant impact on both teaching and research efficiencies. This outcome suggests that 100 percent increase in PFPFTES would result in a 0.0807 and 0.2743 higher in teaching and research efficiency, respectively. The positive contribution of PFPFTES to efficiency implies that the more funding per head from government would enhance the ability to efficiently transform teaching/research inputs into teaching/research outputs. However, based on the estimated coefficients of PFPFTES, the impact of PFPFTES on research efficiency is larger than teaching efficiency.

Conversely, the percentage of public funding in HEIs' revenue (PERPF) has a different impact on teaching and research efficiency. In term of teaching efficiency, PERPF negatively and statistically significant affects the teaching efficiency, but positively on research efficiency. The negative sign of its coefficient in teaching model shows that lower teaching efficiency is with larger proportion of public funding whereas higher teaching efficiency is with smaller proportion. In contrast, the positive sign of its coefficient in research model shows that HEIs with a higher proportion of public funding have higher research efficiency score or another word more efficient. A hundred percent increase in this variable would result in a 0.0810 fall and a 0.5180 up in the teaching and research efficiency, respectively.

The next statistical significance of public funding variable is the percentage of HEIs' investment expenditure in its expenditure (PERINEX). The negative sign of estimated coefficient of PERINEX in both teaching and research model means HEIs with higher percentage of investment expenditure are less teaching and research efficient. The estimated coefficient of PERINEX is -0.1867 in teaching model and -0.0929 in research model which indicates that 100 percent rise in the percentage of investment expenditure in its expenditure is associated with the decrease in teaching and research efficiency of 0.1867 and 0.0929, respectively.

Regarding a group of variables expressing HEIs specific characteristic, there are four variables exhibiting the same positive influence on both teaching and research efficiencies. They are: internal quality score from Self-Assessment Report (IQA_ASSC), HEIs' age (AGEF), dummy variable for public university (PBU), and dummy variable for autonomous university (AUTOU). In the case of IQA_ASSC, the results suggest that the quality aspect of HEIs reflected in internal quality assurance scores have a positively and statistically significant effect on teaching and research efficiencies of Thai public HEIs. However, based on the estimated coefficients of IQA_ASSC, the impact of IQA_ASSC on research efficiency is about six-fold larger than teaching efficiency. Concerning the estimated coefficient of AGEF, it is reasonable to state that younger HEIs are less efficient than the old ones. According to the estimated coefficients of AUTOU, it is obviously seen that autonomous university reveals the highest teaching and research efficiency, compared to other HEIs types. This can be implied might imply that the difference in HEIs' teaching and research efficiencies across HEIs might be due to the degree of autonomy and flexibility of their management that less restrictive management could lead to higher level of teaching and research efficiencies. Although estimated coefficient of PBU exposes the positive relationship to teaching and research efficiencies, it statistically and significantly impacts on research efficiency only.

On the contrary there is only one variable exhibiting the same negatively and statistically significant effect on both teaching and research efficiencies: value of real gross regional product per capita (GRP). Regarding its estimated coefficient of GRP in research model, there is an evidence that HEIs located in areas of high economic prosperity cannot gain benefit from the environment to augment their research efficiency, such as opportunities to cooperate with research intensive companies, to reach modern laboratories, research institutions and big libraries, and to have more appeal when offering research/academic positions due to location. However, in case of teaching efficiency, the results reveal that the estimated coefficient related to the real GDP per capita of the region where the HEIs is located is not statistically significant which can be implied that a development level of the region is not among statistically significant determinants of HEIs' teaching efficiency.

Moreover, there are two variables exhibiting the disparity of an impact on teaching and research efficiencies: dummy variable for having medical faculty (MED) and dummy variable for Rajamangala University of Technology (RMU). As for the estimated coefficient of MED, the results show that the existence of one medical faculty has a positively and statistically significant impact on research efficiency but not on teaching efficiency. This implies that HEIs with a medical faculty are more research efficient. In case of RMU, the results of estimation in teaching model indicate that Rajamangala University of Technology has a higher teaching efficiency than Rajabhat University and public university.

Summarizing effects of independent variables on teaching and research efficiencies are presented in table 5.22.

Table 5.20 Second Stage Analysis Results of Teaching Model, Bootstrap-Truncated Regression estimates

Dependent Variable: BTEFFSC	Estimated Coefficient		SE	Z value	Pr > |Z|	95% Confidence Intervals	
						Lower Bound	**Upper Bound**
(Intercept)	0.6142	***	0.0300	20.4451	0.0000	0.5544	0.6721
Public Funding Variables							
PFPFTES	0.0807	***	0.0076	10.5824	0.0000	0.0651	0.0950
PERPF	-0.0810	***	0.0115	-7.0770	0.0000	-0.1033	-0.0584
PERINEX	-0.1867	***	0.0117	-15.9932	0.0000	-0.2096	-0.1638
HEIs' specific characteristic variables							
GRP	-0.0001		0.0008	-0.1821	0.4278	-0.0014	0.0016
IQA_ASSC	0.0095	***	0.0022	4.2780	0.0000	0.0065	0.0152
AGEF	0.0087	***	0.0031	2.8010	0.0025	0.0025	0.0147

Table 5.20 (Continued)

Dependent Variable: BTEFFSC	Estimated Coefficient		SE	Z value	Pr > |Z|	95% Confidence Intervals	
						Lower Bound	**Upper Bound**
			HEIs' specific characteristic variables				
MEDS	-0.0053		0.0046	-1.1480	0.1255	-0.0138	0.0044
RMU	0.0398	***	0.0042	9.4228	0.0000	0.0315	0.0481
PBU	0.0038		0.0045	0.8391	0.2007	-0.0056	0.0122
AUTOU	0.0528	***	0.0047	11.1408	0.0000	0.0430	0.0616

Notes: * Value of zero does not fall within 90% confidence interval, ** Value of zero does not fall within 95% of confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1500 bootstrapping interactions. Constants are not reported.

Table 5.21 Second Stage Analysis Results of Research Model, Bootstrap -Truncated Regression estimates

Dependent Variable: BTEFFSC	Estimated Coefficient		SE	Z value	Pr > |Z|	95% Confidence Intervals	
						Lower Bound	Upper Bound
(Intercept)	**-0.0239**		0.1339	-0.1785	0.4905	-0.3106	0.2145
			Public Funding Variables				
PFPFTES	**0.2743**	***	0.0292	9.4048	**0.0000**	0.2158	0.3302
PERPF	**0.5180**	***	0.0439	11.7917	0.0000	0.4309	0.6031
PERINEX	**-0.0929**	**	0.0480	-1.9353	0.0265	-0.1878	0.0003
			HEIs' specific characteristic variables				
GRP	**-0.0448**	***	0.0038	-11.8092	**0.0000**	-0.0508	-0.0359
IQA_ASSC	**0.0584**	***	0.0088	6.6047	0.0000	0.0415	0.0761
AGEF	**0.0418**	***	0.0127	3.2980	**0.0005**	0.0167	0.0664
MEDS	**0.2152**	***	0.0175	12.2955	0.0000	0.1830	0.2516
RMU	**-0.0741**	***	0.0152	-4.8746	**0.0000**	-0.1041	-0.0445
PBU	**0.1502**	***	0.0175	8.5986	0.0000	0.1149	0.1834
AUTOU	**0.3161**	***	0.0177	17.8765	**0.0000**	0.2800	0.3493

Notes: * Value of zero does not fall within 90% confidence interval, ** Value of zero does not fall within 95% of confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1500 bootstrapping interactions. Constants are not reported.

Table 5.22 Effects of Independent Variables on Teaching and Research Efficiency

		Teaching Efficiency		Research Efficiency
· Public Funding Variables				
Ratio of public funding to Full Time Equivalent student	+	**Stat. Sig**	+	**Stat. Sig**
Percentage of public funding in HEIs' Revenue	-	**Stat. Sig**	+	**Stat. Sig**
Percentage of HEIs' investment expenditure in HEIs' Expenditure	-	**Stat. Sig**	-	**Stat. Sig**
· HEIs' specific characteristic variables				
Value of real Gross Regional Product per capita	-	**Stat. InSig**	-	**Stat. Sig**
Internal quality score from Self-Assessment Report	+	**Stat. Sig**	+	**Stat. Sig**
Age of HEIs (foundation)	+	**Stat. Sig**	+	**Stat. Sig**
Dummy variable for HEIs with medical school	-	**Stat. InSig**	+	**Stat. Sig**
Dummy variable for Rajamangala University of Technology	+	**Stat. Sig**	-	**Stat. Sig**
Dummy variable for Public University	+	**Stat. Sig**	+	**Stat. InSig**
Dummy variable for Autonomous University	+	**Stat. Sig**	+	**Stat. Sig**

5.2 Policy Implications

There are several implications arise from the empirical Findings of this study. First, since the percentage of efficient HEIs in Thailand is low, the challenge for policy makers is to establish the environment and motivation encouraging HEIs to improve their efficiency. Moreover, although Thai public HEIs have attained a rather high level of efficiency score, this does not mean there is no room for efficiency improvement. In addition, the information about scale efficiency and return to scale also provides HEIs administrators the guidance to achieve a high level of efficiency. Besides, DEA is a very influential benchmarking method employed to discover the most efficient or the best practice HEIs as well as the inefficient HEIs requiring improvement. The administrator of inefficient HEIs could utilize this findings to identify specific adjustments and to implement the approximate approaches for achieving the efficiency frontier. Second, from the policy perspective, the results of investigating the influences of public funding and HEIs characteristic factors on efficiency is very important since it can be helpful to answer the question of what can be done to improve HEIs efficiency. Therefore, HEIs administrators and educational policy makers might take advantages of these findings through properly accurate policy decision in order to make their institutions more efficient.

Several straightforward policy implications emerge from this study including three main aspects: funding reform, governance reform, and teaching and research quality reform.

5.2.1 Funding Reform: Renovation of Government Resource Allocation Mechanism

As regard to the results of investigating influences of public funding on teaching and research efficiencies, it is found that public funding per FTEs positively contributed to teaching and research efficiencies. This implies that to enhance teaching and research efficiency of Thai public HEIs, the pace of public funding for HEIs must be in line with the growth in numbers of student. However, only increases in public funding allocated without enhancing incentive for improving their performance would simply lead to wasteful use of resources. Therefore, allocation of public funding should related to their performance.

Although, the performance-based allocation mechanism has established in Thailand since 2005, up to now the funding system for public HEIs does not fully base on criteria related to their performance as it still relies on a traditional line-item allocation mechanism for distribution of public funding amongst them. Each year, public HEIs submit an annual proposal based on expected outputs. The Bureau of the Budget (BOB) makes the final allocation subjected to the incremental change on a year-to-year basis. Additionally, this allocation mechanism is highly related to bargaining power of each institution. Besides, it does not support the competition among public HEIs in term of searching additional funds from other sources. In addition, it provides no incentive for HEIs to manage their resources efficiently. Furthermore, the amount of resources allocated does not reflects the actual cost structure or performance of the recipients. As a result, the line-item allocation mechanism among other causes is viewed as one main contributing to the current crisis of Thai HE system.

Therefore, the government should employ an innovative allocation mechanism that links funding directly to some measures of teaching and research outputs/outcomes rather than inputs. The following four types of allocation mechanisms for teaching are the example of performance-based that the government might utilize to connect public funding with teaching outputs/outcomes.

1) Performance set-asides where a portion of public funding is set aside to pay on the basis of various performance measures. The performance measures are typically decided through negotiations between a government agency or buffer body and the institutions.

2) Performance contracts where performance contracts typically are regulatory agreements more than legally binding documents and can take a number of forms. Performance-based evaluation criteria are negotiated between government agencies or buffer bodies and institutions. A portion of overall funding may be based on whether institutions meet the requirements in the contracts.

3) Payments for results, where government might apply two ways for funding. First, a set of performance measures is used to calculate institutional eligibility for all or parts of their formula funding of recurrent expenses. Second, government or private entities agree to pay institutions for each student enrolled or degree recipient in certain fields of study or with specific skills.

4) Competitive funds, where the competitive funds are usually funded on a project-by-project basis, typically for the purposes of achieving difficulties through funding formulas or categorical funds, for example to improve quality and relevance, to promote innovation, and foster better management.

Furthermore, government might utilize the following allocation mechanisms to connect public funding with HEIs' research outputs/outcomes or performances.

1) Block grant funding for research: institutions receive a block grant allocation specifically for research activities but not bring differentiated or specified by project. The size and purpose of the block grant may be based on: specific research proposals, institution demonstrated capacity, research centres of excellence in certain fields or endeavours. The block grant levels are largely determined by evaluation of specific project proposals through peer reviews or institutions' capacities to conduct research innovatively.

2) Project Funding: institutions receive allocated funds for research according to proposed projects, usually based on peer reviews of proposals.

5.2.2 Funding Reform: Increasing of HEIs Resources Diversification

As regard to the results from the second stage of study, the source of funding is an important determinant for HEIs efficiency since increasing in percentage of public funding, viewed as non-competitive sources, in total, HEIs' revenue is significantly related to the decrease in teaching efficiency. It seems that HEIs with a higher proportion of public funding, in total, their revenue are less teaching efficient which could depend on the fact that they are not more responsive towards students' needs and use the money in a more efficient way. Moreover, most public HEIs have no incentive to mobilize other resources from all parts of the society. Therefore, for improving teaching efficiency, government should provide environment and financial incentives to encourage HEIs to mobilize resources from various sources for additional revenues.

Diversified financing implies that HEIs are capable of generating their own resources. Generally, HEIs around the world have various ways to diversify their sources of funding other than government budget sources for continuously supporting their institutions, including generating business income from institutional assets, encouraging donations from philanthropists, encouraging public–private partnerships, and mobilizing additional resources from students and their families. However, HEIs should have sufficient autonomy to develop income-generating activities. They should manage their own budget and use the resources they generate in accordance with their development objectives. Moreover, incentive measures are necessary to mobilize both the actors operating the services in question and the institution. The followings are the example of strategies for generating additional resources in public HEIs.

1) Developing philanthropic resources. Philanthropy is an option for additional funding of HEIs. It comes from many different sources: alumni, parents, other individuals, corporations, and foundations. Although not being broadly used in Thailand, given the successful experience of the U.S., the concept of philanthropy seems to be worth exploring in the country.

2) Promoting HEIs-industry relationships. To generate additional income, HEIs can utilize their potential research as a tool by transferring technology, commercial exploitation of knowledge, and partnerships with industry. To strengthen this approach, the government should establish the connection among three partners,

HEIs, industry, and government themselves based on the concept developed by Etzkowitz & Leydesdorff (1997), a “triple helix” model. According to the model, those three partners come together to create a new entity designed to establish knowledge links between HEIs and industry. There are several ways in which HEIs and industry collaborate and these are the examples.

(1) Funded research and resulting technologies with commercial potential (Antunes, 2013)

(2) Student scholarships and fellowships, student internships and recruitment, chaired professorships, classroom and laboratory support and enhancement, advisory board functions (Prigge, 2005)

(3) Creation of spin-off and start-up companies, incubators and science parks (Clark, 1998)

(4) Creation of joint research centres (de Juan, 2003)

3) Generating educational services and Short-term courses. The new market of learners is targeted by many public HEIs. This approach relies on generating new revenues by developing additional academic programs (such as traditional for-credit courses, continuing or professional education, life-long learning initiatives, branch campuses, or study abroad programs) or expanding current ones, focusing not only on students seeking degree programmes but also on students seeking non-degrees pre-and post-baccalaureate certification (see Hearn, 2003; Williams, 1992). Moreover, they should move toward offering special versions of high-demand courses at high tuition levels. Such efforts can include evening courses, summer courses, short courses, online courses, credentialing programs in areas demanded by the labour force and offerings abroad (Hinchcliff, 2000).

Occasionally, new offerings are delivered through partnerships with corporations, governments, or other institutions. For example, HEIs can create state-level partnerships to stimulate workforce training and development in a form of short-term or long-term programmes for industry and other stakeholders. Preferably, such partnerships can provide additional opportunities to generate more revenues (Alstete, 2014). Besides, partnerships can leverage the university’s name and existing course contents with minimal expenditure of time, money, and credibility—all without endangering the exclusivity of the institution’s own degrees (Hearn, 2004). Apart from the organizational level, partnerships may extend to the college, department, researcher, or student. Thoughtfully, this approach requires careful examination of likely financial and nonfinancial cost and return.

4) Leasing HEIs properties. HEIs often own large amount of desirable properties, such as land, contributing to significant institutional revenue. Generally, HEIs have two choices of applying this approach to attain the success: leasing out assets to private entities and establishing independent unit to manage their assets for commercial purposes (Antunes, 2013). Another form of HEIs assets is underutilized facilities that they can rent out or let private enterprises exploit them. For example, many HEIs obtain such revenues through rental, residences, catering, consultancy, libraries, museums, training centres or resource centres, printing and binderies, sport facilities, language centres, scientific test equipment, etc.(Mamo, 2015). In order to clear how free HEIs are to sell or lease or develop or otherwise dispose of their assets without the proceeds being claimed by the government, the non-profit law should be well-developed (Johnstone, 2002).

However, the success in attracting additional funding depends on several factors such as regulatory frameworks, governance and management arrangements. Several scholars have identified that the regulatory frameworks or laws in which public HEIs operate influence their revenue generation efforts (Jongbloed, 2004 and OECD, 2008). The regulatory frameworks often define rules of the game by which various stakeholders interact and exchange resources (Becher & Kogan, 1992:82; Jongbloed, 2004; and OECD, 2008).

Therefore, creating environment for serving public HEIs to generate additional resources, Thai government and HEIs administrators should provide the following incentives.

1) In order to encourage HEIs-industry cooperation basis for the purpose of resources diversification, the government should provide financial incentive on a competitive basis, as follows: subsidies to co-finance collaborations; subsidies for formal collaborations probably driving out equally or more efficient informal contacts; and appropriately use R&D policies for subsidizing national firms. However, these incentives should be implemented with suitable measures, such as: creating HEIs staffs with knowledge transfer skills, professional qualification, and

accreditation scheme; developing a more entrepreneurial mindset; and providing for staff exchanges between research organizations and industry.

2) Since HEIs capacity to generate additional income positively relates to the degree of financial and legal autonomy granted by the regulatory frameworks in which they operate (Estermann, Governance, & Seminar, 2009). However, not all aspects of HEIs autonomy are equally important for influencing revenue generation strategies or activities in HEIs. Procedural autonomy (i.e. financial and staffing autonomy) is highly associated with revenue generation activities or market orientation (De Vries & Koelman, 1999; Jongbloed, 2004, p. 341). This may be because HEIs by their very nature are bottom heavy organizations that have traditionally been a self-governing centre of education and research with adequate substantive autonomy (Dill & Sporn, 1995). Some aspects of financial autonomy include: the extent to which higher education institutions can accumulate reserves and keep surplus on state funding; the ability of higher education institutions to set tuition fees; the ability to borrow money on the financial markets; the ability to invest in financial products; the ability to issue shares and bonds; the ability to own lands and buildings they occupy. As a results, the government should reform the regulatory framework to extend the financial autonomy of HEIs, as aforementioned. Under this changing, public HEIs could enjoy more financial freedom such as facilitation of external funding, possibility to participate in the establishment of businesses, and creation of satellite entities governed under private law.

3) In order to upsurge philanthropic donations, the government could provide philanthropy a favourable tax treatment designed to lessen the tax burdens of donors such as the deduction of tax income on charitable contributions, the foregoing of capital gains taxes on gifts of appreciated property, the avoidance of estate taxes on bequests, and tax deductible gifts providing a stream of income to the donor. Moreover to support philanthropic activities, the government should introduce a matched funding scheme. Under this scheme, contributions are matched by public funds under various conditions. For example, smaller contributions are matched baht for baht by public funds, while bigger ones could be matched at 1:2 or 1:3 with a given ceiling of donation being matched.

4) Many activities aimed to increase and generate new revenue sources need more skilled management at all levels of the institution and may require new expertise which may or may not exist within the institutions. Kirby (2006) argues that one of the strategic actions intended to promote revenue generation in HEIs is related to recruitment, promotion, recognition and reward, and endorsement. As mentioned above, in order to generate new income, Thai public HEIs may recruit professionals from the labour market or invest in staff development to acquire these skills. Moreover, they will have to be increasingly flexible in the management of their human resources, such as recruitment of HEIs staff, setting of more competitive salaries (OECD, 2008). Besides, to increase the staff commitment to revenue generation, a set of incentive mechanisms (financial and non-financial) need to be designed at both staff and faculty/institution.

5.2.3 Governance Reform: Increasing of HEIs Autonomy with Accountability

According to the study's results, autonomous university is more efficient in producing teaching and research outputs than other HEIs types, since they operate under more institutional autonomy as well as flexibility of rules and procedures. Although, autonomous university is still regarded as the government's agencies receiving block grants from the government as usual, they have been granted full status to operate as independent government agencies and are given autonomy to establish their administrative structures or formulate rules and regulations relating to personnel and staffing. The greater independence and flexibility are vital for generating academic environments that are responsive and effective for students' education and for building strong research capabilities. As can be seen from the experience of high-income countries, the most successful HE systems have given full autonomy to HEIs and have established procedures to evaluate education quality and promote healthy competition between institutions.

In case of Thailand, although the 9th Higher Education Development Plan presents clear guidelines to promote HEIs autonomy and states that every HEI should improve their internal management systems in the academic, personnel and financial areas, to eventually evolve into autonomous institutions, the majority of Thai public

HEIs are not autonomous. To encourage institutional autonomy and assist institutions manage the process of becoming more autonomous, Thai government might apply the following recommendations from this study.

1) Separating out the Two Roles of National Government Agencies in the HE Sector

To grant more HEIs autonomy, government agencies involving the management of HE sector have sought to remove government involvement from the day-to-day operation and financial management of the HE sector (Raza, 2010). In Thailand, the government have chosen not to separate these two roles as separated bodies, known as the Office of Higher Education Commissions (OHEC), within the Ministry of Education (MOE) have been established to be responsible for the HE sector. However, there is no clear separation between the two roles of government in OHEC. The government should consider establishing buffer bodies, or alternatives for strengthening the autonomy of OHEC.

2) Aligning Academic and Non-academic Autonomy

Generally, autonomy for HEIs can be divided into two types: academic (including curriculum design, research policy, entrance standards, academic staff appointments, and awarding degrees) and non-academic (including budgeting, financing management, non-academic staff appointments, purchasing, and entering into contracts). However, in Thailand, the government prioritize autonomy in academic areas more than non-academic areas. Lacking of alignment between the two is a problem because they need to work in a complementary fashion (World Bank, 2012). For example, within staffing policies, hiring and firing faculty will depend critically on the ability of institutions to set salaries. Diversifying funding is also an essential means of increasing autonomy. Securing funding from the private sector is particularly important, because it is a critical mechanism for improving efficiency. As HEIs continue to be mostly public bodies reliant on base funding, diversifying funding offers these institutions greater autonomy. In addition, HEIs' ability to pursue new programs or courses fundamentally depends on their procedural autonomy to borrow funds and spend as they like. As a results, the government needs to consider both types of autonomy as a whole since many aspects of academic autonomy can be undermined by the lack of non-academic autonomy.

3) Strengthening Accountability Mechanisms

As HEIs move to higher autonomy, it is very important to align their accountability framework to this new setting. The most important step is to strengthen accountability mechanisms to non-government stakeholders to ensure that autonomy translates into more socially efficient outcomes (World Bank, 2012). There are three mechanisms that can be used as an instrument to strengthen HEIs accountability. However, these two mechanisms should be supported by the government. The first is strengthening and empowering governing boards. This should include the appointment of the board head by the board itself or internal bodies of HEIs as well as the capacity of the board to appoint the president or rector. Boards may need to receive extensive training, particularly in low- income countries. This move may also require keeping a limited number of members but preserving broad representativeness, which is essential to strengthen the client power relationship. The second is strengthening the exit option for students. This will entail steps to increase mobility and competition including national qualification frameworks, disclosure and publication of information on institutional and graduate performance, and some demand-side financing.

4) Creating an Enabling Environment for Higher Education Reform

According to investigating factor influencing the success of HE reform by Raza (2010), several factors are important in creating an enabling environment for the success: generating ownership of the reform process, building institutional capacity, and prioritizing establishing the legislative framework.

(1) Generating Ownership of the Reform Process. The successful outcomes of HEIs reform are usually driven by domestic ownership of the reform process and by a political consensus that decentralizing higher education management is better for the economic needs of the country. Consequently, to ensure that key stakeholders, particularly HEIs themselves, see the merits of how a decentralize system can potentially benefit them and dialogue with the government whereas other key stakeholders need to be placed on.

(2) Building Institutional Capacity. Reforms often stumble because capacity is not in place either within the government or within the HEIs and the lack of capacity also makes the government vary in pursuing the reform (World Bank,

2012). Building up capacity in areas such as financial management before the reformation can be an essential agenda for HEIs.

(3) Prioritizing Establishing the Legislative Framework. Inadequately sequencing of reform can slow the process, and prioritizing and getting the legislative framework right is the key of successful reform (World Bank, 2012). The legal focus, rightly so, has prioritized the change of public HEIs into autonomous independent entities. However, what is equally important is to ensure that the overall legislative framework is adequately reformed to accommodate the new autonomous role of the publicly owned institutions.

5.2.4 Teaching and Research Quality Reform

DEA method employed in this study for investigating the teaching and research efficiency of Thai public HEIs is very powerful benchmarking tool to identify the most efficient or the best practice HEIs for inefficient HEIs and quantifying the gaps to be fulfilled in order to become efficient. According to the study result, autonomous university can be classified as the most efficient HEIs type in both teaching and research. Once the specific changes are recognized in the inefficient HEIs, their administrators can implement appropriate actions to become the efficient HEIs. Certainly, these actions would have the potential to make the inefficient HEIs move toward the best practice HEIs. Moreover, information about HEIs performance can be employed to support transferring the better system and managerial expertise of efficient to inefficient HEIs.

The five specific changes, introduced by ADB (2011, 2012), that could be implemented by inefficient HEIs are as follows.

1) To improve teaching quality by enhancing the capacity of academic staff

Enhancing teaching quality leads to greater teaching efficiency and improving student learning. Students can be educated more effectively and efficiently if teaching quality is strong. To improve teaching quality, institutions-based professional development centres should be established with professionals who are knowledgeable about effective ways to organize and deliver faculty professional development. Providing academic staff with opportunities to learn proven teaching methods that foster active and engaged learning. The followings are the recommended topics: 1) curriculum planning and course design based on intended learning outcomes, 2) strategies for linking teaching methods and student learning assessment methods to intended learning goals, 3) strategies that foster active learning, and 4) strategies that prepare students to engage in new forms of learning. Moreover, institutions professional development centres should help academic staffs enhance their research skills, as well as their knowledge about labour market opportunities for students in their fields.

2) To improve faculty incentive and evaluation systems

To engage fully in work that best supports the missions and goals of the institution, academic staffs must be clear about what those goals are, have the abilities and skills to do the expected work, and believe that there are sufficient incentives and rewards to make it worthwhile to do the work. Fair and transparent evaluation systems are closely related to effective incentive and reward systems. HEIs administrators should: 1) articulate institutional goals and priorities and the expectations for the role of academic staffs in advancing the priorities; 2) provide professional development that ensures staff have the skills and abilities to meet the expectations; and 3) develop evaluation systems based on fair, consistent, and transparent assessment of performance and linked with valued incentives.

3) To better the alignment of HEIs curricula and instruction with labour market needs

The alignment can be improved without assaulting the central role of higher education (ADB, 2011). Overlap in institutional missions and duplication in instructional programs should be minimized. Letting market forces determine the range of subjects studied in higher education can go only so far in improving HEIs efficiency. Thai public HEIs can improve their efficiency by increasing the amount of emphasis on soft skills in higher learning, including cross-disciplinary perspectives, critical thinking, and collaborative problem solving—skills demanded by the changing workplace. Thailand is in desperate need of graduates in science and technology fields. Therefore, the government should assist HEIs in pursuing proactively experimental initiatives aimed at improving responsiveness to labour market needs. Moreover, the supplement project operations should be established to support HEIs in experimenting with units or centres that: 1) draw staff from inside and outside the university; and 2) are more directly focused on newly emerging industries such as software production, energy, and environmental protection and green economies. Besides, HEIs should give such centres more autonomy than other academic units but would permit them to solicit additional funding on their own.

In case of research efficiency, developing HEIs-based research efforts consistent with individual institutional missions along with improving public-private and cross-border research partnerships is recommended.

1) Developing HEIs-based research efforts consistent with individual institutional missions

Research productivity is the currency of international prestige in higher education. Because of the stretching of HEIs resources, institutional research efforts should match with specific institutional missions. In countries where HE systems comprised of institutions with differentiated missions, institutions may take different approaches to research. In order to improve HEIs research productivity, the government should encourage them to examine how their research fits with specific institutional missions as well as reward research activity specifically aligned with institutional missions. Moreover, the supplement project operations should be established for facilitating cross-institutional discussion of diverse approaches to research and inquiry government. Besides, the projects could assist in sponsoring professional research training programs designed to strengthen the research skills of individual researchers.

2) Improving public-private and cross-border research partnerships

A major driver of research productivity is cross-border collaboration, such as partnership with commerce or industry, or across borders. To strength the collaboration and partnership, it is necessary for coordination and consultation among various partnership programs. Each public-private partnership emphasizes a different aspect of capacity development in research. As a results, the government should assist HEIs to improve their policy frameworks in ways that allow and encourage high-quality research partnerships between the HEIs and private commerce and industry by establishing project operations providing technical assistance for improving legal frameworks and for designing research approaches that facilitate collaboration and enable to help second-and third-tier HEIs take a leading role in applying research to practical problems that confront the local communities they serve. Moreover, the projects operations can provide support to help utilize advances in ICT and increase the efficiency of research productivity by linking remote HEIs to their national counterparts and to other HEIs across national borders. In addition, the projects can support cross-border collaboration aimed at facilitating regional centres of research excellence that effectively enhance regional capacity and productivity.

CHAPTER 6

CONCLUSION

Under the control of the Office of Higher Education Commission (OHEC), there have been 172 public HEIs which encompass about two million students and over fifty thousand academic staffs. This is a dramatic expansion compared to 78 HEIs in 2002 when Rajabhat and Rajamangala universities were not yet under the control of the Ministry of Universities Affairs (Changed to the OHEC in 2003). According to their establishment legislation as follows, there were 16 public universities (including 14 limited admission universities and 2 open admission universities), 16 autonomous universities, 40 Rajabhat Universities, 9 Rajamangala Universities of Technology, 19 community colleges. On the other hand, the 71 private HEIs consists of 39 private universities and 32 private colleges/institutions. Although, there is not much different in terms of institute numbers (102 public versus 72 private institutions), Thai HE system is dominated by a public sector. There are 85.67 % of students registering in public HEIs while the private ones have a share of only 14.33 %. Rajabhat universities have the highest number of student enrolment, about 27.34 % of students pursuing HE study. Open universities consisting of only two institutions but having the second highest enrolment of student, which is 21.26 %. This is followed by limited admission universities which has 15.63 % of students. As regard to the number of instructors, autonomous universities have the largest share with 33.43 % followed by Limited admission universities and Rajabhat universities with 21.20 and 19.57, respectively.

In the last decade, the Thai government aims to boost productivity of a public higher education sector, which has been the engine for promoting labour productivity, competitiveness and economic growth. However, the role of Thai HE sector is questioned due to various evidences of its performance. According to the latest 2016-2017 Global Competitiveness Report of World Economic Forum, Thailand's score on the area of "higher education and training" is low. Its rank is 62 out of 138 countries.

Compared to other key Asian trading partners, Thailand is lagging behind Singapore (2), Malaysia (39), Hong Kong (22), Taiwan (9), South Korea (17), and Japan (21). It is generally recognized that HE system in Thailand has encountered several problems. According to OEC (2003), the noticeable problems of Thai HE system are: lack of unity in public policies, goals and direction; absence of a strong and effective mechanism to monitor and evaluate the performance of Higher Education Institutions (HEIs); lack of mechanism to support and assist HEIs in initiating and developing innovations; lack of flexibility and efficiency in the administration and management of HEIs; and the absence of cooperation within and outside the institutions. Besides, HE also confronts with other problems such as, equity in accessing to HEIs (Kirtikara, 2001, Sangnapaboworn, 2003); public funding system (Puntasen et al., 2003; Weesakul, B. et al., 2004; Tangkitvanich & Manasboonphempool, 2011); quality of learners and educational personnel (OEC, 2009); and the structural mismatch between offered and needed skills (Di Gropello, 2011). Among various issues of Thai HE system, public funding system for HE should be primarily concerned as it is merely a mechanism to allocate financial resources to HEIs and students but a crucial way to improve the unsatisfactory performance of HE system.

In order to improve HEIs' performance, the HE public funding system might be employed as a governance instrument. The fact that the public funding system for Thai HE is facing a number of problems as revealed above, it is, therefore, fascinating to investigate whether the current public funding system can be employed as the governance instrument to promote the performance of HEIs. Simultaneously, it is also important to further explore whether the performance of Thai HEIs could be affected by factors other than HE public funding system. Moreover, the empirical study on the effect of public funding system for HE on HEIs' performance has been non-available in Thailand, as the author's knowledge.

The main aim of this study is to evaluate teaching and research efficiency of Thai public HEIs and to investigate the significance of public funding along with potential factors in improving their efficiency in term of teaching and research. Unlike most of the previous studies in Thailand context, to attain the aim, this study employed the two-stage analysis.

To satisfy the objective, the study gathers data of public HEIs in Thai HE system during the years 2010-2012. The main source of HE data is OHEC which provides information on inputs and outputs of HE production. For the purpose of maintaining their homogeneity, some HEIs types are excluded from the analysis such as Open University (Ramkhamhaeng University, Sukhothai Thammathirat Open University), Monk University (Mahamakut Buddhist University, Mahachulalongkornrajavidyalaya University), and those which mainly devotes to educate and train only for graduate studies level (National Institute of Development Administration). The final sample comprises of 55 public HEIs of which complete data are available for the years 2010-2012.

6.1 Summary of Major Empirical Findings

In the first-stage analysis, to evaluate relative teaching and research efficiency on a sample of 55 Thai public HEIs for Thai public HEIs over the period between 2010 to2012, this study used a DEA method (the method to estimate a production frontier in multi-input/output case). However, in public HE sector, resources allocated to them are more or less fixed, and they cannot easily adjust their inputs such as academic or non-academic staff, capital, etc. without government approval. Consequently, the output-oriented approach is considered to be more appropriate for constructing a DEA model in public HE context. Moreover, to comply with the real world that the optimal scale under the CRS assumption is often precluded by a variety of circumstances such as different types of market power, constraints on finances, externalities, imperfect competition, this study, then, deploys the DEA model with VRS assumption, called Output-oriented DEA-BCC Model, to obtain teaching and research efficiency of Thai public HEIs. Moreover, to scrutinize whether Thai public HEIs operate at the optimal scale size in production of teaching and research, the teaching and research scale efficiency are computed. However, the usefulness of scale efficiency is limited, as it demonstrates only the existence of scale inefficiency without suggestion the nature of return to scale (RTS) which is the valuable information for managerial decision making. Therefore, the nature of RTS is identified by using Färe and Grosskopf (1985)'s scale efficiency index

The results, over three years, of the first-stage analysis reveal that the majority of Thai public HEIs are teaching and research inefficient. Only 26.67 and 36.36 % of public HEIs are teaching and research efficient, respectively. Over time of study, the percentage of teaching efficient HEIs decreases whereas the one of research efficient HEIs increases. Surprisingly, only 7.27 % of Thai public HEIs achieves both teaching and research efficiency frontier. Regarding the number of teaching and research efficient HEIs across their types, autonomous university has the largest share of both teaching (53.33 %) and research (60.00 %) efficient HEIs. In contrast, Rajabhat University has the lowest share of teaching efficient HEIs (16.09 %) while public university has the lowest percentage of research efficient HEIs (20.00 %).

Regarding teaching, the findings disclose a rather high level of average teaching efficiency score at 0.9415. This implies that, on average, teaching inefficient HEIs could expand the producing of teaching output (given technology and input level) by 6.21 % to order to reach the teaching efficient. Additionally, their teaching efficiency varies across HEIs types while, autonomous university has the highest level of average teaching efficiency score over three years (0.9745), followed by Rajamangala University (0.9414), HEIs type that has the lowest average teaching efficiency score is Rajabhat University (0.9306).

Moreover, to examine the source of teaching inefficiency of Thai public HEIs, teaching scale efficiency is computed. The findings reveal that the minority of Thai public HEIs are teaching scale efficiency (13.94 %) and at the same time they are teaching efficient HEIs. This implies that these HEIs operate on the efficient frontier and achieve the highest productivity. In other word, the teaching efficiency arise from both good management of resources (teaching efficiency) and producing at the optimal scale (teaching scale efficiency). The remaining, 12.73 % of public HEIs, can operate on the teaching efficient frontier, but cannot obtain the optimal scale production. Incredibly, 47.73 % of Thai public HEIs are unable to attain both teaching and scale efficiencies. To compare the percentage of teaching scale efficient HEIs across HEI Types, the results reveal that autonomous university has the largest share of 30.00 %, followed by Rajabhat University (11.49 %). In contrast, public university has the lowest share of 6.67 %.

Besides, the average of teaching scale efficiency scores is rather low (0.6468) as lower than the average teaching efficiency score (0.9415). This indicates that, overall, teaching inefficiency of Thai public HEIs is mainly caused by inappropriate production scale. As regard to teaching scale efficiency score across HEIs types, autonomous university has the highest level of average teaching scale efficiency scores (0.8401), followed by Rajamangala University of Technology (0.6583) whereas Rajabhat University has the lowest level of average teaching scale efficiency scores (0.5916).

As mentioned above, the key source of teaching inefficiency in the Thai HE system seems to be scale related, thus, it is important to identify returns to scale of Thai public HEIs in producing teaching. The findings reveal that most of HEIs (86.06 percent) operate at DRS. This means that they are deemed to be operated above the optimal scale of teaching production. Therefore, they could increase their level of productivity by reducing the size of operation.

With regard to research, the findings expose a rather low level of average research efficiency score at 0.7467. To be research efficient HEIs, the research inefficient HEIs should enlarge their producing of research output (given technology and input level) by 33.91 percent. Furthermore, the research efficiency of Thai public HEIs diverges across HEIs types. The findings reveal that, autonomous university has the highest level of average research efficiency score over three years (0.8835), followed by public university (0.7485), while Rajabhat University has the lowest level (0.7003).

Additionally, to examine the source of research inefficiency of Thai public HEIs, research scale efficiency is calculated. The findings show that there exist only 28.48 % of HEIs which operate on the research efficient frontier and achieve the highest level of productivity. This implies that their research efficiency arises from both good management of resources (research efficiency) and producing at the optimal scale (research scale efficiency). Conversely, there are 63.64 % cannot attain both research pure and scale efficiency. The remaining percentage of public HEIs (7.88 %) is able to operate on the research efficient frontier, but cannot obtain the optimal scale production.

Regarding research scale efficiency score, an average score is rather high (0.9352) as it is higher than the average research efficiency score (0.7467). This implies that research inefficiency of Thai public HEIs is mainly caused by the ability to manage their resources for producing research but not the scale of production. Similar to teaching scale efficiency, research scale efficiency scores vary across HEIs types. Autonomous university has the highest level (0.9855), followed by public university (0.9812) while Rajabhat University is at the lowest level (0.8995).

Although research inefficiency of Thai public HEIs slightly relates to scale of production, it is still reasonable to examine sources of research scale inefficiency by identifying returns to scale in production of research. The findings demonstrate that the majority of Thai public HEIs tend to operate at IRS in producing research. Each year, there exists around 50.00 % of HEIs operate at IRS while the remaining, around 30% and 20%, operate at CRS and DRS, respectively. This implies that a half of Thai public HEIs are deemed to be operated below an optimal scale and could increase their level of productivity by expanding the size of operation. HEIs exhibiting DRS might decrease their productivity through reduction below their current scale of production. Dissimilarly to teaching production, the return to scale of research production varies across HEIS type. Over three years, the majority of Rajabhat University, Rajamangala University of Technology, and public university (accounted for 55.77 %, 55.56 %, and 46.67 % respectively), operate at IRS. On the other hand, the large parts of autonomous university (accounted for 55.67 %) operate at CRS.

In the second-stage analysis, contrary to the previous studies in Thai HE context, this study utilizes the double bootstrap truncated regression, based on Simar & Wilson (2007), to investigate the accuracy of estimated influences of public funding and potential factors on teaching and research efficiency which may be helpful to answer the question of what can be done to improve HEIs' efficiency. In the first bootstrap procedure, a set of bias-corrected DEA-efficiency scores and confidence intervals is calculated. Subsequently, in the second bootstrap procedure, the bias-corrected efficiency scores from the first procedure are regressed on public funding variables and environmental variables describing HEIs' characteristics to obtain coefficient of these variables and their standard errors.

Concerning public funding variables, the results from the second-stage analysis indicate that ratio of public funding to FTEs contributes positively to the teaching and research efficiency, This implies that to enhance teaching and research efficiency of Thai public HEIs, the pace of public funding for HE being in line with the growth in number of students since the funding reduction to FTEs causes negative influences on both teaching and research efficiency. In contrast, the percentage of investment expenditure in all HEIs' expenditure has a negative impact on teaching and research efficiency. This means that the higher HEIs' expenditure on HEIs investment, the lesser teaching and research efficient, because it is possible there is smaller budget left for efficiency improvement. Besides, the source of funding is an important efficiency determinant since increasing in percentage of public funding in total HEIs' revenue is related to the downfall of teaching efficiency, but the increase in research efficiency.

In case of HEI's characteristic variables, one interesting result indicates higher teaching and research efficiency with larger internal quality assurance score. However, based on the estimated coefficients of IQA_ASSC, the impact of IQA_ASSC on research efficiency is about six-fold larger than teaching efficiency. Moreover, it is reasonable to state that younger HEIs have less teaching and research efficiency than the old ones. According to dummy variables representing HEIs types, autonomous university is the type of the highest teaching and research efficiency. This implies that the degree of autonomy and flexibility of management impacts on efficiency, in direction that less restrictive management could lead to higher level of teaching and research efficiency. Besides, evidences show that HEIs located in areas of high economic prosperity are unable to gain the benefit from the environment to improve their research efficiency. On the contrary, the regional development is insignificant determinants for HEIs' teaching efficiency. Furthermore, the existence of one medical faculty has a positively and statistically significant impact on research efficiency but not on teaching efficiency since the medical faculty is more inclined to receive earnings from research grants than others.

6.2 Policy Implications

Several straightforward policy implications emerge from this study including three main aspects: funding reform, governance reform, and teaching and research quality reform (as detailed in chapter 5. These aspects can be classified into four topics as follows:

1) Funding Reform: Renovation of Government Resource Allocation Mechanism

Since increasing in public funding allocated to HEIs without enhancing incentive for improving their performance would simply lead to wasteful use of resources, allocation of the public funding to HEIs should relate to their performance. Although, the performance-based allocation mechanism has established in Thailand since 2005, up to now, the funding system for Thai public HEIs does not fully base on criteria related to their performance. It still relies on a traditional line-item allocation mechanism for distribution of public funding amongst public HEIs. Additionally, this allocation mechanism is highly related to bargaining power of each institution. Besides, it does not support the competition among public HEIs in term of searching additional funds from other sources. In addition, it provides no incentive for HEIs to manage their resources efficiently. Furthermore, the amount of resources allocated does not reflect the actual cost structure or performance of recipient institutions. As a result, the line-item allocation mechanism among other causes is viewed as one main contribution to the current crisis of Thai HE system.

Therefore, the government should employ an innovative allocation mechanism that links funding directly to some measures of teaching and research output/outcome rather than inputs. The following four types of allocation mechanisms for teaching are the example of performance-based that the government might utilize to connect public funding with teaching outputs/outcomes: 1) Performance set-asides; 2) Performance contracts; 3) Payments for results; and 4) Competitive funds.

Furthermore, government might utilize the following allocation mechanism to connect public funding with HEIs' research outputs/outcomes or performance: 1) Block grant funding for research; 2) Project Funding: institutions receive allocated funds for research according to proposed projects, usually based on peer reviews of proposals.

2) Funding Reform: Increasing of HEIs Resources Diversification

In order to create environment for public HEIs to generate additional resources, Thai government and HEIs administrators should provide the following incentives.

(1) In order to encourage HEIs-industry cooperation basis for the purpose of resources diversification, the government should provide financial incentive on a competitive basis as follows: subsidies to co-finance collaborations; subsidies for formal collaborations probably driving out equally or more efficient informal contacts; and appropriately use R&D policies for subsidizing national firms. However, these incentives should be implemented with the suitable measures.

(2) Since the capacity to generate additional income positively relates to the degree of financial and legal autonomy granted by the regulatory framework in which they operate, the government should reform regulatory frameworks to extend the financial autonomy for HEIs, as aforementioned. Under this changing, public HEIs could enjoy more financial freedom such as facilitation of external funding, possibility to participate in the establishment of businesses, and creation of satellite entities governed under the private law.

(3) In order to upsurge philanthropic donations, the government could provide philanthropy a favourable tax treatment designed to lessen the tax burdens of donors such as the deduction of income tax on charitable contributions, the foregoing of capital gains taxes on gifts of appreciated property, the avoidance of estate taxes on bequests, and tax deductible gifts providing a stream of income to the donors. Moreover to support philanthropic activities, the government should introduce a matched funding scheme.

(4) Many activities to increase and generate new revenue sources need more skilled management at all levels of the institution and may require new expertise which may or may not exist within the HEIs. In order to generate new income, Thai public HEIs may recruit professionals from a labour market or invest in staff development to acquire these skills. Moreover, they have to be increasingly flexible in the management of their human resources, such as recruitment of HEIs staff, setting of more competitive salaries.

3) Governance Reform: Increasing of HEIs Autonomy with Accountability

Although the country's 9th Higher Education Development Plan presents its clear guidelines to promote HEIs autonomy and states that every HEI should improve their internal management systems in academic, personnel and financial areas to eventually evolve into autonomous institutions, the majority of Thai public HEIs are not autonomous. To encourage institutional autonomy and assist institutions to manage the process of becoming more autonomous, Thai government might apply the following recommendations from this study: 1) separating out the two roles of national government agencies in the HE Sector; 2) aligning academic and non-academic autonomy; 3) strengthening accountability mechanisms; 4) creating the enabling environment for HE Reform.

Moreover, there are several factors which are important in creating the enabling environment for the successful governance reform: 1) generating ownership of the reform process; 2) building institutional capacity; and 3) prioritizing the legislative framework establishments.

4) Teaching and Research Quality Reform

The DEA method employed in this study for investigating the teaching and research efficiency of Thai public HEIs is very powerful benchmarking tool to identify the most efficient or the best practice HEIs and, as for inefficient HEIs, to quantify the gaps to be fulfilled in order to become efficient. According to the study result, autonomous university can be classified as the most efficient HEIs type in both teaching and research. As for inefficient HEIs, once their administrators can implement appropriate actions to become the efficient ones. Certainly, these actions would have the potential to make the inefficient HEIs move toward the better practice. Moreover, information about HEIs performance can be employed to support the transferring toward the better system and managerial expertise.

The five specific changes that could be implemented for inefficient HEIs to approach the best practices: 1) improving teaching quality by enhancing the capacity of academic staff; 2) improving faculty incentive and evaluation systems; 3) constructing better align university curricula and instruction with labour market needs; 4) developing HEIs-based research efforts being consistent with individual institutional missions; 5) improving public-private and cross-border research partnerships

6.3 Contributions of the Study

There are four contributions to the existing literature of efficiency measurement in Thai HE sector in this study. First, this study is the first attempt to investigate teaching and research efficiency on multiple inputs and outputs of 55 Thai public HEIs during the period of 2010-2012. Second, this study examines teaching and research efficiency and its determinants by using the new method that has never been utilized in Thai HE sector: two-Stage Double-Bootstrap Data envelopment Analysis, proposed by Simar and Wilson (2007). Third, to the best of the author's knowledge, this study is the first study in Thailand that uses panel data to analyse teaching and research efficiency and its determinants of Thai public HEIs. Finally, efficiency scores derived for the period 2010-12 are recent findings on teaching and research efficiency in Thai HE sector.

6.4 Limitations of the Study

However, one should be aware of the limitations of this study. First, it is very difficult to select HEIs inputs and outputs to reflect their performance. Second, the DEA method has some limitations in itself: the sensitivity of extreme observations or failures in the units referred as efficient; and the sensitivity of the total number of inputs and outputs (the greater it is, the greater the probability to be efficient is). Third, one should aware that DEA defines efficiency in a relative manner, so it could be the case that a unit on the frontier of efficiency may is not very efficient, but others conduct even worse. Finally, data available on HEIs inputs and outputs is also another limitation as the number of public HEIs used in this study is, then, only 55 out of 79. As a result, the study findings cannot be generalized throughout the Thai public HE sector

6.5 Areas of Further Research

Hence, this study could be viewed as the first step for a more detailed analysis of the topic where more work can be done on improving the study by introducing qualitative data especially with regard to the teaching and research. Besides, the Malmquist approach can be applied with panel data to investigate the improvement on teaching and research efficiency of Thai public HEIs as well as total factor productivity and technical change. Although it would also be very fascinating to compare the patterns of teaching and research efficiencies in public and private HEIs, the unavailability of data (especially concerning funding) for private HEIs remains the major impediment. Finding another and a better set of inputs and outputs for efficiency models would be also highly desirable. Further extensions of the study include the benchmarking of HE performance with those of other developing countries at a similar stage of development. The focusing points would be identifying the area of improvement and determining what policies should be implemented in the HE sector.

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