EFFICIENCY ANALYSIS OF HIGH-COST DENTAL PROSTHETIC SERVICE PROVISION IN THAI DISTRICT HOSPITALS UNDER UNIVERSAL HEALTHCARE COVERAGE SCHEME IN FISCAL YEAR 2010-2011

Mr. Chanapong Rojanaworarit

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การวิเคราะห์ประสิทธิภาพการให้บริการฟันเทียมที่มีค่าใช้จ่ายสูงในโรงพยาบาลชุมชน ภายใต้โครงการหลักประกันสุขภาพถ้วนหน้าของประเทศไทย ปีงบประมาณ ๒๕๕๓-๒๕๕๔

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By	Mr. Chanapong Rojanaworarit
Field of Study	Public Health
Thesis Advisor	Associate Professor Sathirakorn Pongpanich, Ph.D.
Thesis Co-advisor	Associate Professor Supawat Rungsuriyawiboon, Ph.D.

Accepted by the College of Public Health Sciences, Chulalongkorn University in Partial Fulfillment of the Requirements for Degree of Doctor of Philosophy

……...…….. Dean of the College of Public Health Sciences
(Professor Surasak Taneepanichskul, M.D.)

THESIS COMMITTEE

…… Chairman
(Professor Surasak Taneepanichskul, M.D.)

……. Thesis Advisor
(Associate Professor Sathirakorn Pongpanich, Ph.D.)

……. Thesis Co-advisor
(Associate Professor Supawat Rungsuriyawiboon, Ph.D.)

……. Examiner
(Assistant Professor Ratana Somrongthong, Ph.D.)

……. Examiner
(Alessio Panza, M.D., M.P.H.)

……. External Examiner
(Bunjong Chumpa, Ph.D.)

ชนพงษ์ โรจนวรฤทธิ์ : การวิเคราะห์การให้บริการฟันเทียมที่มีค่าใช้จ่ายสูงในโรงพยาบาลชุมชนภายใต้โครงการหลักประกันสุขภาพถ้วนหน้าของประเทศไทยปีงบประมาณ ๒๕๕๓-๒๕๕๔. (EFFICIENCY ANALYSIS OF HIGH-COST DENTAL PROSTHETIC SERVICE PROVISION IN THAI DISTRICT HOSPITALS UNDER UNIVERSAL HEALTHCARE COVERAGE SCHEME IN FISCAL YEAR 2010-2011) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.ดร. สถิรกร พงศ์พานิช, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ.ดร.ศุภวัจน์ รุ่งสุริยะวิบูลย์, 195 หน้า

การศึกษานี้มีวัตถุประสงค์หลักในการวัดประสิทธิภาพเชิงเทคนิคของการให้บริการฟันเทียมที่มีค่าใช้จ่ายสูงภายใต้โครงการหลักประกันสุขภาพถ้วนหน้าในโรงพยาบาลชุมชนในประเทศไทย โดยเป็นกรณีศึกษาโรงพยาบาลชุมชนทุกขนาดทั่วประเทศ จำนวน 663 และ 709 แห่ง ในปีงบประมาณ 2553 และ 2554 ตามลำดับ การวิเคราะห์ใช้เทคนิคการวิเคราะห์ล้อมกรอบข้อมูล (Data Envelopment Analysis, DEA) โดยการวัดประสิทธิภาพเชิงเทคนิค ใช้ข้อสมมติลักษณะผลตอบแทนแบบ variable returns to scale และมีการจำแนกปัจจัยการผลิตของบริการเป็น 2 ส่วนคือ จำนวนทันตแพทย์ที่ปฏิบัติงาน และ ค่าใช้จ่ายดำเนินการ เปรียบเทียบกับผลผลิตของบริการฟันเทียม 4 ประเภท กล่าวคือ ฟันเทียมทั้งปากถอดได้ฐานอะคริลิคชนิดที่ใส่ในสันเหงือกบนหรือล่างอันใดอันหนึ่ง ฟันเทียมทั้งปากถอดได้ฐานอะคริลิคชนิดใส่ในสันเหงือกทั้งบนและล่าง ฟันเทียมบางส่วนถอดได้ใส่ฟันไม่เกิน 5 ซี่ และฟันเทียมบางส่วนถอดได้ใส่ฟันเกิน 5 ซี่ ในปีงบประมาณ 2553 โรงพยาบาลมีประสิทธิภาพเชิงเทคนิคในการให้บริการโดยเฉลี่ย 69.1% และมี 133 แห่งที่เป็นหน่วยบริการที่มีประสิทธิภาพระดับแนวหน้า ส่วนในปีงบประมาณ 2554 โรงพยาบาลมีประสิทธิภาพเชิงเทคนิคในการให้บริการโดยเฉลี่ยลดลงเหลือ 64.8% และมี 109 แห่งที่มีประสิทธิภาพระดับแนวหน้า ในส่วนการวิเคราะห์ปัจจัยที่มีผลต่อประสิทธิภาพการผลิตบริการโดยการวิเคราะห์โทบิต (Tobit analysis) พบว่า ขนาดของโรงพยาบาล(ตามขนาดจำนวนเตียงผู้ป่วยใน)และการที่โรงพยาบาลตั้งอยู่ในเขตภาคกลางมีความสัมพันธ์เชิงบวกแต่จำนวนทันตแพทย์ที่มากขึ้นในหน่วยบริการกลับมีความสัมพันธ์ในเชิงลบกับประสิทธิภาพการให้บริการดังกล่าว ในส่วนการศึกษาเชิงคุณภาพเพื่อสังเคราะห์บทเรียนเชิงบริหารจัดการจากโรงพยาบาลที่มีประสิทธิภาพชั้นแนวหน้าที่มีขนาดต่างกัน 3 แห่งพบว่ามีลักษณะเด่นคือ มีระบบการจัดการผู้มารับบริการและให้ความสำคัญกับการจัดสรรเวลาเพื่อให้บริการฟันเทียมได้ในเวลาไม่นาน มีการกระจายผู้รับบริการให้ทันตแพทย์ทุกคนในฝ่ายได้ให้บริการโดยไม่จำกัดเฉพาะทันตแพทย์เฉพาะทาง และมีรูปแบบการทำงานเชิงรุกเพื่อให้บริการในชุมชน

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ปีการศึกษา 2555 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก.....

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม.....

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This study evaluates technical efficiency in provision of high-cost dental prosthetic service under Universal Healthcare Coverage Scheme in Thailand. The study takes 663 and 709 district hospitals of all sizes nationwide as analyzed firms in fiscal year 2010 and 2011, respectively. Data Envelopment Analysis (DEA) is applied for relative efficiency measurement based on assumption of variable returns to scale. Two production inputs comprise number of dentists in each hospitals and operating expenses. Four production outputs are defined by different types of removable acrylic dentures including single denture, complete denture, partial denture with not more than 5 replaced teeth and partial denture with more than 5 replaced teeth. Among all analyzed firms in fiscal year 2010, average efficiency is found to be around 69% and 133 technically efficient firms are identified. For 2011, average efficiency is decreased to be about 65% with 109 efficient firms identified. In addition to the technical efficiency measurement, relationship between explanatory factors and the dependent variable of efficiency scores is investigated by means of Tobit analysis. Hospital sizes (indicated by numbers of inpatient beds) and hospital location in the central region of the nation are positively related to efficiency in service production while increase in number of dentists is instead negatively associated with the technical efficiency. To gain better understanding of current situation of the dental prosthetic service provision and to generate lessons learned from best practice dental providers, qualitative part of this thesis is undertaken by means of in-depth interview in three technically efficient hospitals of different sizes. Key managerial strategies to achieve service efficiency of these efficient providers comprise allocation of working hours specific for the prosthetic service, assigning edentulous patients to all dentists instead of limiting the service to be served only by prosthodontist, and extension of the dental prosthetic service provision to Health Promoting Hospitals at sub-district level with public relation through local community network.

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LIST OF ABBREVIATIONS

BCC	Banker, Charnes, and Cooper (1984)
CCR	Charnes, Cooper, and Rhodes (1978)
CPI	Consumer Price Index
CRS	Constant Returns to Scale
CSMBS	Civil Servant Medical Benefit Scheme
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
IAF	Inflation Adjustment Factor
IRS	Increasing Returns to Scale
MOPH	Ministry of Public Health
NHSO	National Health Security Office
POP	Posterior occluding pair
PTE	Pure Technical Efficiency
PV	Present Value
SE	Scale Efficiency
SFA	Stochastic Frontier Analysis
SSS	Social Security Scheme
TE	Technical Efficiency
TE_{crs}	Technical Efficiency Measure under CRS assumption
TE_i	Input-oriented Technical Efficiency
TE_o	Output-oriented Technical Efficiency
TE_{vrs}	Technical Efficiency Measure under VRS assumption
THB	Thai Baht
TPF	Total Factor Productivity
UC	Universal Healthcare Coverage Scheme
VRS	Variable Returns to Scale
WCS	Workmen's Compensation Scheme
WHO	World Health Organization

CHAPTER I

INTRODUCTION

1.1 Background and Rationale

Tooth loss in Thai populations is a common consequence of progressive dental caries and periodontal diseases (Division of Dental Public Health, 2008: 36-38). Secular trends of tooth loss in Thai adults (35-44 years old) and elders (60-74 years old) have been improving from 1984 to 2007 as indicated by increasing percentages of individuals with at least 20 functional remaining teeth in both age groups (Division of Dental Public Health, 2008: 36-38). In spite of the mentioned improving trend, tooth loss has continued to be a major dental public health problem in 82.84% of Thai adults with average loss of 3.92 teeth per person and 94.04% of the elderly with average loss of 13.38 teeth per person, as revealed in the lastly completed national dental survey (Division of Dental Public Health, 2008: executive summary). Total edentulousness or total loss of teeth could also be found up to 10.47% of the elderly (Division of Dental Public Health, 2008: 36).

Without placement of dental prosthesis to restore masticatory function, edentulousness is more potential to affect change in dietary intake, especially decrease in consumption of vegetables and fiber-rich foods, due to limitation of chewing ability (Joshipura, Willett, and Douglass, 1996: 459-467). The adverse alteration in dietary habit can even contribute to development of chronic diseases, such as cardiovascular disease and cancer (Hung et al., 2003: 1185-1192; Joshipura et al., 1996: 459-467). Edentulism can also adversely affect facial esthetics, self-confidence, and several aspects of oral health-related quality of life (Davis et al., 2000: 503-506; Fiske et al.,

1998: 90-93; Gerritsen et al., 2010: online; Sowmya, Vinaya, and Krishna Prasad, 2011: 34-36). Since total loss of teeth is more likely to be found among individuals with lower socioeconomic status (Esan, et al., 2004: online), access to high-cost dental prosthetic service is then limited by financial barrier.

On account of the mentioned evidences, National Health Security Office (NHSO) in Thailand has thus provided a channel for individual insured by Universal Healthcare Coverage Scheme (UC) to obtain dental prosthesis free of charge at a registered local public hospital with an aim to provide financial aid and improve access to this high-cost dental intervention (Bureau of Claim Administration, 2012: 242-243). In consideration of high-cost characteristic of the dental prosthetic service and attempt of budgetary control, financing method of this program is then specifically assigned. Unlike other routine dental interventions which are funded by pre-paid contract capitation system (National Health Security Office [NHSO], 2011: 169-170), the high-cost dental prosthetic program is financed through fee-for-service reimbursement system with accountancy audit in attempt to control program expenditure (Bureau of Claim Administration, 2012: 33-49).

From health economic point of view, health resources–such as healthcare personals, service time, instruments, health budget and others–are scarce and would not suffice excessive need of healthcare service (Jiruth Sriratanaban, 2000: 1-2). Evidences of limited supply of the high-cost dental prosthetic service (Bureau of Claim Administration, 2011) and a considerable number of edentulous patients being underserved of the dental prosthetic service (Division of Dental Public Health, 2008: 67) would simply illustrate that the mentioned principle holds true in current situation of service provision. Providing the high-cost dental prostheses under UC has thus

posed great challenges to public dental service management in terms of financial viability risk due to limited health budget; need of balancing between demand of chewing appliances by a large number of partial and total edentulous patients and the service supply based considerably on dentists' decision to forgo their busy chair time for other routine dental services to entail time-consuming and multiple-visit process of denture fabrication (Roney, 2011 : online; Shay, Grasso, and Barrack, 2010 : online); and adaptation of local dental units to conform the mentioned unique high-cost service reimbursement system (Bureau of Claim Administration, 2012: 33-49).

Regarding financial viability risk, excessive provision of such dental service would potentially result in budget overrun. For instance, in case of complete denture provision for patients with total loss of teeth, estimated operating cost for each set of complete denture provided through this program could be as high as 4,400 Thai Baht (THB) (Bureau of Claim Administration, 2012: 242-243), which was nearly twice as much as UC per capita funding of 2,401.33 and 2,546.48 THBs in fiscal year 2010 and 2011 respectively (NHSO, 2010: 11, 2011: 6-7). However, avoiding the risk by limiting provision of the dental service would adversely cause long waiting queues of patients with some edentulous spaces or even no teeth to chew, aggravated oral health-related quality of life (Davis et al., 2000: 503-506; McMillan and Wong, 2004: 172-176), and poor patient satisfaction with the dental service (Wungchun Kittipadakul et al., 2005: 29-43). Concept of efficiency would be useful in guiding a strategy for better management of this challenging situation. Efficiency analysis would suggest possible way of maximizing dental prosthetic service outputs given constraints of limited funding and fixed amount of other service production inputs. Then, the financial viability risk can be better managed. In addition, optimizing

related health resources–especially the funding–to deliver a certain extent of the dental prosthetic service can also be considered.

Nevertheless, since the dental prosthetic program has been financed through global budgeting system together with other high-cost medical equipment and interventions (Bureau of Claim Administration, 2012: 41-48), specific budgetary value of this dental service has not been separately estimated. Such inclusive funding has raised a basic question about how much the global budget has been allocated to this dental prosthetic program. Moreover, since definite budget of a certain healthcare service is crucial information for deciding on what extent of the service should be provided, knowledge about the budget is then useful for rational service delivery planning in consecutive fiscal years. In attempt to respond to the mentioned issues, the National Dental Fund has been established in fiscal year 2011 to undertake one of its tasks to estimate specific budget for the high-cost dental prosthetic program (Wirut Eungpoolsawat et al., 2011: online). Despite such effort, rational budgeting specifically for high-cost dental prosthetic service is still in an early stage. In lack of definite budgetary value, real extent of dental prosthetic service delivery and related value of service reimbursement identified at the end of previous fiscal years would be better evidences for efficiency analysis. Consequently, a crucial task to be undertaken is to identify such baseline information through analysis of service delivery in recent fiscal years.

Variation in extent of dental prosthetic service delivery among different hospitals would also be on account of the fact that there is neither compulsory regulation nor incentive given to dentists in addition to salary to influence such provision. As mentioned earlier, dentists providing this service would play a very

important role in specifying extent of the service delivery since they are free to make their own judgment on such an issue. Pattern of dental service provision would thus be potentially deviated on account of dentist-related factors (Brennan and Spencer, 2005: 181-195). For instance, dentists' decision whether to provide the prosthetic service shortly after case finding or to put these dental patients on waiting list and give priority to other single-visit interventions would influence extent of the prosthetic service provision in different hospitals. How efficient the dental prosthetic service can be delivered to patients would be considerably dependent on decision and performance of the dental providers. Therefore, efficiency analysis regarding this service which includes dentists as one of major service production inputs would provide objective measurement of their performance in dental prosthetic service delivery. In addition, the measure of service delivery performance can further be compared across different hospitals providing the same kind of service. Hospitals with high performance in delivery of this service would become benchmarks for other hospitals in terms of efficient service management strategy. Additional investigation of these benchmarks by means of qualitative case study would enable synthesis of efficient service management lessons for other hospitals to consider for further improvement of their dental prosthetic service delivery.

Various factors may influence efficiency in dental prosthetic service delivery. Capacity in delivering the service may vary by different hospital sizes. Urban-rural difference can also result in variation of dental prosthetic service rates (Bader, Scurria, and Shugars, 1994: 26-30). Locations of dental units are found to influence difference in pattern of dental service provision as well (Brennan, Spencer, and Slade, 1996: 157-162). Nonetheless, relationship between these factors and efficiency in

dental prosthetic service delivery, especially in the context of Thailand, has received very little investigation. Knowledge about such relationship would complement understanding of factors which either enable or hinder efficient dental prosthetic service provision by local service providers. For example, if dental units situated in very rural areas may be found to be inefficient in delivery of the prosthetic service compared to those situated in more urbanized areas, influence of different degrees of rurality can then be determined and policy makers can further investigate the underlying reasons at local context in order to support accordingly. Based on this rationale, the relationship between factors–including hospital sizes, dental specialties, degrees of rurality, and geographical regions–and efficiency in the dental prosthetic service delivery should thus be examined.

1.2 Justification and Contribution of the Dissertation

Public provision of high-cost dental prosthetic service under UC at district hospital level in Thailand is analyzed in this dissertation. As earlier mentioned, the high-cost dental prosthetic program has been financed through fee-for-service reimbursement system with accountancy audit under authority of the Bureau of Claim Administration of NHSO (Bureau of Claim Administration, 2012: 33-49). This reimbursement system enables the Bureau of Claim Administration to systematically collect evidences regarding extent of the high-cost dental prosthetic service delivery and related operating expenditure from district hospitals nationwide and develop into national database concerning this service provision (Bureau of Claim Administration, 2011). Availability of the national database further provides an opportunity for

research on themes of health financing and efficiency analysis of public dental service in Thailand which has been limitedly investigated.

Although efficiency analysis should also be undertaken for other routine dental services provided by public hospitals under UC in Thailand, there are some limitations which hinder practical conduction of such research. First, unlike reimbursement system of the high-cost complete denture service, other routine dental services are financed through UC per capita funding locally managed by hospitals themselves (NHSO, 2011: 169-170). Consequently, report of dental service delivery extent and related expenditure from local dental providers to NHSO is not normally obtained. Lack of such crucial information disables systematic collection of the needed evidences and development of national database concerning other routine dental services. Therefore, by the time of completing this dissertation, national database of the high-cost dental prosthetic service is still the best available evidence at national level which can be practically used for efficiency analysis of public dental service in the context of Thailand. Second, even though the data regarding service delivery extent and related expenditure of other routine dental services can be directly obtained from each public hospital, it is quite impractical to complete collection of such information for efficiency analysis at national level–concerning need of substantial research funding, considerable time spending which hinders prompt analysis for expeditious action, current controversy about definitions of some intervention codes used in record–such as the case of unidentified clear-cut between simple and complicated dental extraction, and ready availability of this database which can be promptly used for pioneering efficiency analysis. Third, although sampling method may also be applied to draw representative dental units, there is

always chance to leave out some significant dental units from efficiency analysis. Since data envelopment analysis (DEA) used for efficiency analysis in this dissertation is a data-oriented technique, different sets of sampled dental units included into analyses would potentially result in different technical efficiency frontiers estimated by the DEA. An apparent instance is when a real best practice dental unit is left out due to random sampling; another dental unit, which is actually less efficient in service production compared to the left out unit, may instead become an efficient dental unit on estimated technical efficiency frontier. Consequently, other inefficient dental units are benchmarked against the dental unit which is not actually the best practice dental unit.

Based on these previously-mentioned reasons, the best available evidences of high-cost dental prosthetic service implemented nationwide are used for this pioneering study on a theme of efficiency analysis of public dental service provision in the context of Thailand. The efficiency analysis in this dissertation utilized parameters concerning the selected dental service of all district hospitals nationwide to contribute to the extensive view on efficiency of the dental prosthetic service delivery at the national level.

Selection of the high-cost dental prosthetic service for efficiency analysis in this dissertation is not solely driven by availability of the national parameters, but also driven by other important features of this service which are appealing for research and development. These features of the dental prosthetic service are summarized as followed:

- High-cost routine dental service with a large number of eligible service users and service recipients
- Considerable burden of tooth loss anticipated to continue
- The only routine dental service included in the list of high-cost medical care interventions under expenditure management by the Bureau of Claim Administration
- Evidence of budget overrun
- Optimal condition for performance measurement of public dental service delivery

Provision of the dental prosthetic service is considered to be a routine dental service widely delivered by public hospitals ranging from those of large size, such as regional and provincial hospitals, to smaller-sized district hospitals throughout the nation. The UC beneficiaries with partial or total tooth loss are eligible users of the dental prosthetic service. Although demand for this service among UC beneficiaries has not been estimated, burden of the service is considered to be significantly large. The massive service burden is considered from several available evidences. First, a large number of eligible service users are taken into account. In fiscal year 2010, there were approximately 47.2397 million UC beneficiaries (NHSO, 2010: 10) or about 73.9% of the total population of 63,878,267 in Thailand (Ministry of Interior, 2010 : online). In the consecutive fiscal year of 2011, there were also up to 47,996,600 registered UC beneficiaries nationwide (NHSO, 2011: 6) which was about 74.9% of the total population of 64,076,033 (Ministry of Interior, 2011: online). The eligible service users are theoretically of wide age range, including those of late teenage age

to the elderly (John et al., 2004: 125-132). Second, number of service recipients is another indicator of service extent to be considered. The dental prosthetic service has been delivered nationwide to 63,177 and 69,383 partial and total edentulous patients in fiscal year 2010 and 2011, respectively. Third, considerable burden of tooth loss is anticipated to be continued. Based on the secular trend of periodontal diseases in adults and elders in Thailand, severe periodontitis as indicated by presence of periodontal pocket of 6 millimeters depth or more has neither been decreased in adult population nor in the elderly (Division of Dental Public Health, 2008: 37-38). Although, the trend of having at least 20 functional remaining teeth seems to be improved, many of these remaining teeth have been assessed to be in disease condition (Division of Dental Public Health, 2008: 37). Based on these evidences, research undertaken in this dissertation would somewhat suggest policy implications for improvement of the dental service which benefits considerable group of population.

Among all routine dental care interventions provided in district hospitals, provision of dental prostheses–especially provision of complete denture for total edentulous patient– is the most expensive dental service (Arthorn Riewpaiboon, 2010: online). According to standard cost list for health technology assessment, estimated direct costs for provision of dental prostheses in district hospitals are as followed (Arthorn Riewpaiboon, 2010: online):

- Removable acrylic denture with ≤ 5 replaced teeth = 1,166 THB
- Removable acrylic denture with > 5 replaced teeth = 1,360 THB
- Single denture for total edentulism in either dental arch = 2,332 THB
- Complete denture for total edentulism in both dental arches = 3,984 THB

Due to the high cost of service production, the dental prosthetic service has become the only routine dental service included in the list of high-cost medical care intervention under expenditure management by the Bureau of Claim Administration (Bureau of Claim Administration, 2012: 206-244). Even with the specialized reimbursement system, there was an apparent evidence of budget overrun as indicated by large discrepancy between estimated budget for the dental prosthetic service (162,433,051.26 THB) and excessive service reimbursement (216,177,636.70 THB) at the end of fiscal year 2011 (Bureau of Claim Administration, 2011). Efficiency analysis of this costly service production would then be beneficial as an objective evaluation method to assess relative technical efficiency in service delivery among district hospitals nationwide. With constraints of limited number of dental professionals and restricted funding, efficiency analysis would additionally guide possible way to maximize service outputs. On the other hand, efficiency analysis would also suggest optimization of service inputs to produce fixed extent of the service provision. Moreover, service delivery extent and reimbursement information would also be useful for budget estimation which is relevant to the practical context.

Efficiency is important for service production management regardless of sector– public or private–that a certain firm belongs to. For private firm, efficiency is a very important for being competitive in market competition. Inefficient firm with extravagant use of resource inputs or excessive cost of service production would be at high financial viability risk. The firm may not be able to generate sufficient income to sustain its operation and this would ultimately lead to bankruptcy. Unlike the private firm, public firm–such as dental unit of district hospital–can survive financial viability risk even with inefficient operation due to annual government funding. (Direk

Patmasiriwat, 2009: 79-84) Therefore, to objectively evaluate performance of dental units of district hospitals which are public firms producing dental prosthetic service requiring considerable government spending, efficiency analysis method is thus employed in this dissertation in attempt to primarily address inefficient aspects of the service production. Condition of the dental prosthetic service is suitable for efficiency analysis using DEA technique in that, as well as delivery of many other healthcare services, healthcare providers are not expected to be fully efficient (Hollingsworth, Dawson, and Maniadakis, 1999: 161). In other words, some degree of inefficiency always exists and there is opportunity for further improvement. Examples of some inefficient aspects of the dental prosthetic service in this context of analysis are unavailability of complete denture service in some dental units, considerable length of waiting lists, and the mentioned budget overrun. Consequently, DEA is a practical tool for objective performance measurement since the technique can measure firm-level inefficiency without prior assumption that all analyzed firms are fully efficient (Coeli et al., 2005: 161). Another aspect that makes the dental prosthetic service appealing for efficiency analysis and efficiency improvement is non-emergency, multiple-visit nature of the service production. Dental emergencies, such as severe dental pain and dental trauma, are usually given the first priority due to aggressive symptoms and need of prompt treatment. Single-visit dental interventions; such as dental extraction, dental filling, and full mouth scaling; are also more likely to be immediately provided since these interventions can be completed in one visit and the numbers of delivering these services are usually recognized as common key performance indicators of local dental units. Unlike dental emergencies and single-visit dental interventions that the problems of long waiting lists and patients being

underserved are less common, patients requesting the dental prosthetic service are usually screened on the first visit and put in waiting queue for a period of time. Multiple clinical and laboratory steps for denture fabrication, need of post-insertion check-up and correction, and need of multiple visits to hospital further complicate service production and account for several aspects of inefficiency in service delivery. The non-emergency nature of the service also causes great dependence on dentist's decision whether to provide the dental prosthetic service shortly after the first screening. This dependence on professional decision further provides opportunity for research to assess professional performance measurement in terms of service management and the condition of the service delivery is so ideal in that neither incentive is additionally given to dentist as positive reinforcement for delivering more service nor regulation is applied as negative reinforcement to force the dentist to deliver the service. The dentists are thus free to make decision and apply their own service management strategy.

Scope of efficiency analysis in this dissertation is restricted to district hospitals under authority of Ministry of Public Health in Thailand. This scope restriction allows assumption of efficiency analysis in this context of analysis in that all analyzed firms are the most significant providers of the dental prosthetic service in their corresponding districts. Market share by public-private partnership in providing this public service, which confounds efficiency analysis of a certain firm, is very limited (Bureau of Claim Administration, 2012: Database).

This dissertation also contributes to understanding of factors associated with technical efficiency of district hospitals in production of the dental prosthetic service. Factors; including hospital size, number of affiliated dentists, and location of firm in

the central region compared to location in all other regions combined; are taken into analysis by means of Tobit regression analysis.

In attempt to provide constructive suggestion for practical improvement of efficiency in delivering the dental prosthetic service and for policy makers to positively support local dental units in such service provision, in-depth investigation concerning service management strategy by means of qualitative case study method is also undertaken. Best practice dental units earlier identified by the DEA are selected for qualitative study to generate practical lesson for other dental units on management strategy of the service. Suggestion from these benchmarks would also provide feedback to policy makers regarding implementation of policy, address some aspects of policy which may not be practical in local context of service delivery, and raise some issues for further policy development.

Two most recent fiscal years of 2010 and 2011 are selected for analyses in this dissertation. Fiscal year 2010 is chosen to highlight transitional fiscal year prior to attempt of budget estimation specifically for dental prosthetic service by the National Dental Fund, and the first fiscal year when new internet-assisted E-Claim system has completely functioned. Situation analysis in fiscal year 2010 can thus provide information regarding service delivery extent and related expenditure which was actually not concluded and documented by the time of budget estimation for fiscal year 2011. Information of fiscal year 2010 would also provide baseline reference for comparison with that of fiscal year 2011 in this thesis and other later fiscal years in the future. Fiscal year 2011 highlights establishment of the National Dental Fund which includes budget estimation specifically for the dental prosthetic service as one of its responsibility. Comparison of the estimated budget and real value of service

reimbursement can then be documented for further improvement in budgeting and service delivery planning.

1.3 Research Questions

1) What is relative technical efficiency of high-cost dental prosthetic service under UC among public dental units of Thai district hospitals nationwide?

2) What are factors affecting technical efficiency of high-cost dental prosthetic service under UC among public dental units of Thai district hospitals nationwide?

3) What are characteristics and management strategies of best practice dental units as obtained by means of qualitative study?

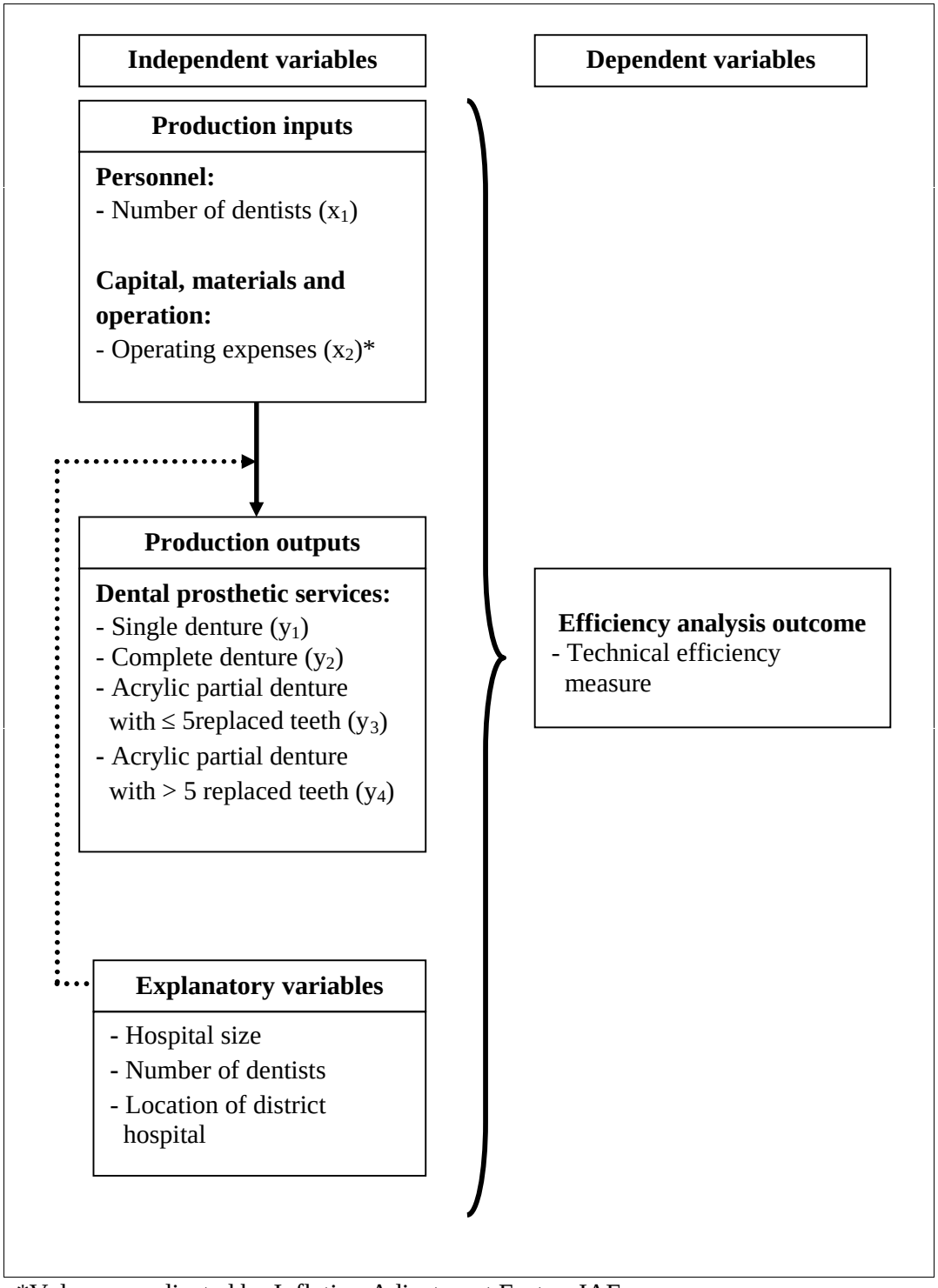
1.4 Research Objectives

1) To assess relative technical efficiency of high-cost dental prosthetic service under UC among public dental units of Thai district hospitals nationwide.

2) To identify factors affecting technical efficiency of high-cost dental prosthetic service under UC among public dental units of Thai district hospitals nationwide.

3) To describe characteristics and management strategies of best practice dental units as obtained by means of qualitative study.

1.5 Conceptual Framework



*Values are adjusted by Inflation Adjustment Factor, IAF.

1.6 Variable definitions and measurement

1.6.1 Production-related variables:

Variables:	Units:	Definitions:
(1) Number of dentists (x_1)	Person	Number of affiliated dentists in each dental unit
(2) Operating expenses (x_2)	Thai Baht (THB)	Operating expenses account for capital, materials, transportation and dental laboratory expenses.
(3) Outputs:	Depend on types of dental prostheses	Depend on types of dental prostheses
(3.1) Single denture (y_1)	Piece	Number of piece per one production of this prosthesis
(3.2) Complete denture (y_2)	Set (1 set = 2 pieces)	Number of set (or two pieces) per one production of these prostheses
(3.3) Acrylic partial denture with ≤ 5 replaced teeth (y_3)	Piece	Number of piece per one production of this prosthesis
(3.4) Acrylic partial denture with > 5 replaced teeth (y_4)	Piece	Number of piece per one production of this prosthesis

1.6.2 Explanatory variables:

Variables:	Units:	Definitions:
(1) Hospital size	Inpatient bed numbers (10, 30, 60, 90, 120 or more)	Size of district hospital specified by MOPH
(2) Number of dentists	Person	Number of affiliated dentists in each dental unit
(3) Location (by geographical regions)	Thai geographical regions: Central, North, North-east, East, South, and West	

1.6.3 Dependent variable:

Variable:	Definition:
(1) Technical efficiency measure	Measure of dental unit's ability in production of high-cost dental prosthetic service using aforementioned service production inputs (dentist and operating expenses).

1.7 Expected Benefits

1) This study would exemplify application of DEA technique as an alternative performance measurement approach to objectively evaluate relative technical efficiency of dental units at district hospital level in providing high-cost dental prosthetic service in the context of Thailand.

2) This study would exemplify utilization of routine dental information to evaluate relative performance of dental units in delivering a certain dental service.

3) This study would provide baseline information regarding service delivery extent and related operating expenses of the high-cost dental prosthetic service in fiscal year 2010 and 2011. The baseline information would be beneficial for improvement of budget estimation by the National Dental Fund in later fiscal years.

4) Input-oriented DEA model would suggest possible way of optimizing related health resource inputs–especially the service funding–when delivering certain extent of the dental prosthetic service. This approach would be beneficial in decreasing loss from excessive use of related health resource inputs for production of this service. Pure technical efficiency measure could be useful in identifying excess in amount of inputs used in production of the service which could be minimized to reduce loss.

5) Technical efficiency score of a certain dental unit would primarily indicate its performance in dental prosthetic service delivery in comparison with other included dental units providing the same dental service. Areas of inefficiency in production of the service can also be addressed for each dental unit. Consequently, specific suggestion for each dental unit to improve its efficiency in delivery of the service can be provided.

7) Best practice dental units can be identified from the efficiency analysis. These high-performance dental units would become benchmarks or role models of efficient service management. Lesson regarding efficient service management strategy qualitatively generated from these best practice dental units would be beneficial for other dental units to learn and apply for further efficiency improvement.

1.8 Preliminary Limitations of Research

1) Although this study has well adopted fully-validated parameters regarding high-cost dental prosthetic service in two fiscal years, such panel parameters are still limited in illustrating technical change analysis in efficiency analysis phase. Collection of parameters in longer period would be needed for such research objective.

2) Since claim for service reimbursement made by local dental units is based on charge prices and estimates of some operating cost items, operating costs of service production in this context of analysis are therefore not precisely identified. Operating costs used in the efficiency analysis of this dissertation are then estimated by value of service reimbursement. The term ‘operating expenses’ is thus used instead of ‘operating costs’ throughout this dissertation.

3) Due to ethical consideration, names of all district hospitals are not declared. Results with names of these district hospitals will be disclosed only to authorized personnel and organization (Bureau of Claim Administration and NHSO) which will directly use the information for policy improvement and implementation.

4) For dental units identified to be inefficient in the efficiency analysis, further investigation of underlying reasons will only be authority of Bureau of Claim Administration and NHSO.

CHAPTER II

NATIONAL DENTAL SERVICE PROFILE

This chapter provides informative description of Thailand's national dental service profile in order to ease understanding of the context of analysis in this dissertation. This chapter is organized into 4 main parts. This first part of this chapter initially describes oral health situation in Thailand with the focus on three major dental public health problems: dental caries, periodontal diseases, and tooth loss. Progressive dental caries and periodontal diseases usually lead to ultimate condition of tooth loss. These problems are commonly found among Thai adults and elders who are target population of the dental prosthetic service. The second part provides information concerning dental system in Thailand with focus on three main aspects: organizational structure, oral healthcare financing schemes, and provision of public dental service in Thai district hospitals. The third part is devoted to detailed description of the high-cost dental prosthetic service which is the major interest in this dissertation. Ultimately, the last part provides overview of efficiency issues in health service provision. Explanation in this part is related to three aspects including performance measurement in health service provision, market mechanism and exceptional features of health system, and relationship between quality and efficiency in health system.

2.1 Oral Health Situation in Thailand

Surveys of oral health status in Thai populations have been conducted every five years since 1977. By the time of this dissertation in 2012, the Seventh National Dental Survey has been commenced but not yet completed. Thus, oral health situation and trends discussed here are based mostly on recent complete report in 2008 and other previous surveys.

Although the oral health problem focused in this dissertation is tooth loss, description of oral health situation here is not limited to such a problem due to the fact that tooth loss is likely to occur after overt progression of dental caries and periodontal diseases (Jaafar, Razak, and Nor, 1989: 39-41). Moreover, experience of oral diseases in earlier ages would result in accumulative damage to dental and periodontal organs, need of dental restorations or complicated dental treatments, and final consequence of partial or total loss of teeth in the more advanced ages (Hugoson et al., 2005: 139-155). Therefore, to reflect the continuum of disease progression and subsequent outcomes, this section reviews secular trends of oral health problems in Thai populations from younger ages to the more advanced ages with conclusion of situation emphasizing the problem of tooth loss.

According to the results of the last five times of complete dental surveys, secular trends of some oral health indicators specified by World Health Organization (WHO) have gradually been improving (Division of Dental Public Health, 2008: Executive summary). Featured findings are summarized as followed:

(A) Dental Caries

To indicate personal dental caries experience in primary health care facility, DMFT index recognized by WHO is used especially in dental survey. The D element stands for decayed or carious teeth without treatment, M is for missing teeth caused by dental caries, F is for filling or restoration due to dental caries, and T implies index per tooth. Assessment in regard to DMFT index is based only on clinical examination while dental radiographic exam is excluded from the process. (Becker et al., 2007: 677-681)

Dental caries situation in children has long been of great concern since the secular trend of dental caries occurrence in deciduous teeth indicated by DMFT index is as high as more than 3 teeth per child and the occurrence rises with age to 5-6 teeth per child by the age of 5-6 years old. The age of initial dental caries experience is as low as 3 years old. Nevertheless, there is an improving sign of dental caries occurrence trend is showed by the ratio between children without dental caries (caries-free condition) and their counterpart in both age groups of 3 and 5 years old, especially in the last two surveys. (Division of Dental Public Health, 2008: 35) The mentioned trend is represented in Figure 2.1.

Even with the increase in percentage of caries-free children in the last survey, dental caries continues to affect 61.63% of the 3-year-olds and as high as 80.64% of the 5-year-olds. Major factors influencing high caries occurrence in children are poor oral hygiene care and sweetened milk intake. Compromised quality of oral hygiene care is indicated by the fact that only 36.35% of the 3-year-olds have parents- or guardian-aided oral hygiene care. Sweetened milk intake at home is also found in 46.69% of pre-school children, regardless of the non-sweetened milk provision

program in child development centers and kindergartens. (Division of Dental Public Health, 2008: Executive summary)

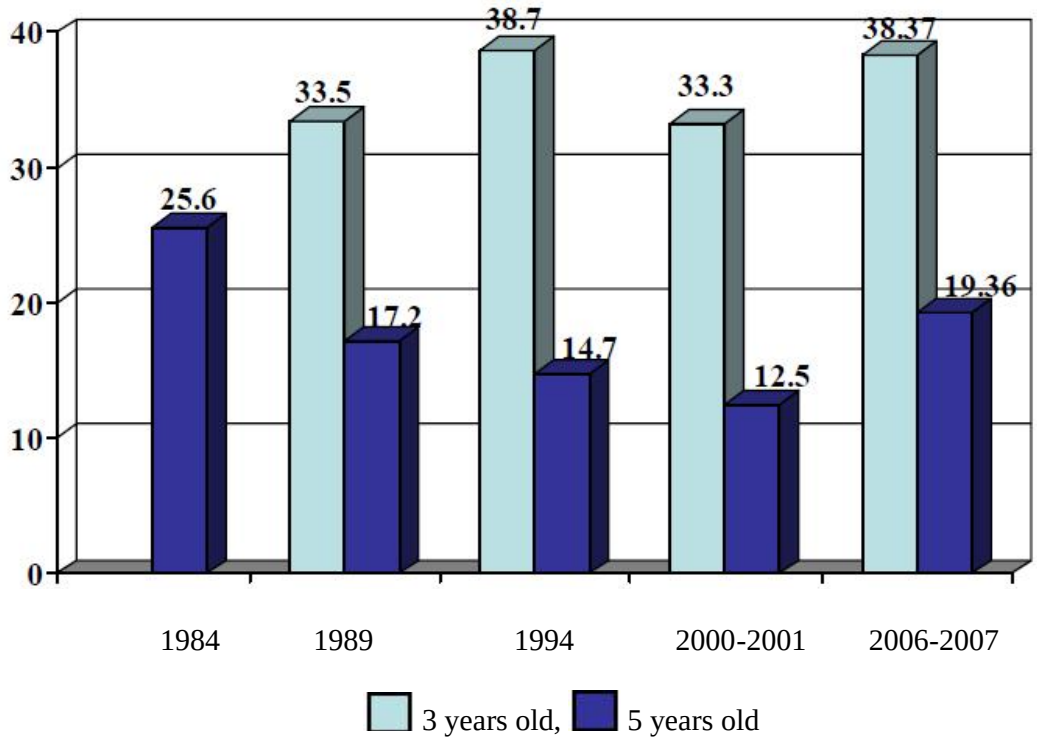


Figure 2.1: Percentages of caries-free children in 3 and 5 years old groups from the National Dental Surveys in Thailand

(Source: Division of Dental Public Health, 2008: 35)

There is a remarkable difference between the secular trends of dental caries occurrence in permanent teeth of 12-year-olds living either in urban or rural areas. Decreasing trend of dental caries occurrence is found in those residing in urban areas while increasing trend is contrastively found in the other group. Consequently, when both groups are merged for total consideration, the overall trend is not clearly an improving trend. Even with a slight drop of the overall dental caries occurrence in the last survey, the occurrence is still as high as 56.87%, indicating that more than half of

the 12-year-olds have dental caries. (Division of Dental Public Health, 2008: 36) The mentioned trends are illustrated in Figure 2.2.

Although a large number of 12-year-olds are found to have dental caries, the average number of affected teeth per person is still low. This is indicated by DMFT indices assessed in the last two surveys which are found constant at 1.55 teeth / person (Division of Dental Public Health, 2002; and Division of Dental Public Health, 2008). Low DMFT values determined in this group of Thai adolescents are consistent with the pattern of low DMFT values (range from 1.2 to 2.6) found in most Asian countries (Peterson et al., 2005: 661-669).

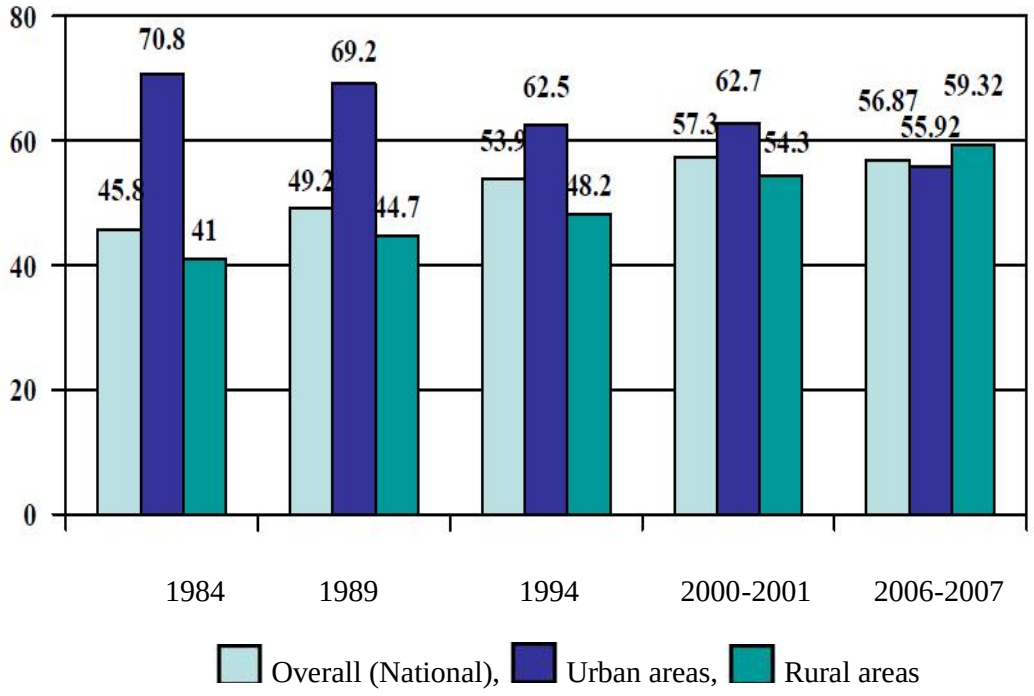


Figure 2.2: Percentages of dental caries occurrence in 12-year-old adolescents from the National Dental Surveys in Thailand

(Source: Division of Dental Public Health, 2008: 36)

Improved access to preventive dental care is believed to contribute to the constant caries occurrence in 12-year-old children of the last survey. This notion is supported by a finding that 12.7% of 12-year-old children have received dental sealant in the last survey, which is greater than 4.5% found in 2001 survey. This increase in dental sealant provision is enabled by Universal Healthcare Coverage Scheme (UC) which includes dental sealant in its dental benefits for children. School-based oral health promotion program is also an effective measure for caries control in these children. Nevertheless, soft drink and snack intake continues to raise the risk of dental caries in this age group. (Division of Dental Public Health, 2008: Executive summary) Above all, importance should be given to the fact that dental caries has never been completely wiped out and the appropriate dental public health goal is thus to control the disease to a specific level of severity (Peterson et al., 2005: 661-669).

Dental caries in Thai adult and elderly populations

Dental caries is highly prevalent among Thai adults and elders and this oral problem usually leads to tooth loss. Approximately 89.57% of Thai adult population aged 35-44 years old has dental caries. Tooth loss is also found in 82.84% of this population. Tooth loss apparently occurs in adulthood and continues into advanced age. Among Thai elders aged 60-74 years old, prevalence of dental caries is founded to be up to 96.15%. Prevalence of tooth loss in this population is also as high as 94.04%. Average number of tooth loss per person in the elderly is more than 10 teeth per person. Just slightly more than half of the elders (54.80%) are found to have at least 20 functional teeth. (Division of Dental Public Health, 2008: 21)

Posterior occluding pairs (POP) is an indicator of chewing efficiency (Miranda et al., 2002: Online). Theoretically, 8 POPs or 4 pairs of antagonistic teeth on each

side are expected for perfect condition. Nonetheless, only 4 POPs are expected to allow practical chewing. Average number of POPs in Thai adult population is 6.95 pairs per person. The number of POPs sharply decreases down to 3.27 pairs per person in the elderly. It should be noted that almost all Thai elders with the age of 80 and older have no longer functional remaining teeth left in their mouths according to the finding of 1.28 POPs on average. (Division of Dental Public Health, 2008: 21)

(B) Periodontal Condition

Gingivitis or inflammation of the gum continues to be extensively found in 58.94% of the 12-year-olds in the last survey. Moreover, up to half of these adolescents with gingivitis are determined to additionally have dental calculus. Nevertheless, the problem of gingivitis in this age group has been improved as indicated by an increasing secular trend of normal gingival condition found especially in the last two surveys. In another group of adolescents aged 15 and 17-19 years old, the trend of normal gingival conditional also resembles the mentioned trend in 12-year-olds (See Figure 2.3). (Division of Dental Public Health, 2008: 37-38)

Periodontal Diseases in Thai adult and elderly populations

Periodontal diseases, which are advanced pathological forms of gingival tissues and alveolar bone destruction potentially resulting in tooth loss, tend to be more prevalent in Thai adults (35-44 years old) and elders (60-74 years old). In the last survey, periodontal diseases are found in 37.6% of adults and up to 84.2% of the elders. Severe periodontal diseases, indicated by presence of periodontal pocket with at least 6 mm depth, are found in 68.8% of the elders (See Figure 2.4). This is an

important sign representing great likelihood of tooth loss in near future. (Division of Dental Public Health, 2008: 37-38)

Smoking is still determined as a major contributing factor for periodontal diseases in these two age groups. About 20.98% of adults are smokers with an average of 10.38 cigarettes smoked per day while 17.87% of the elders are smokers with lower average of 7.47 cigarettes per day. (Division of Dental Public Health, 2008 Executive summary)

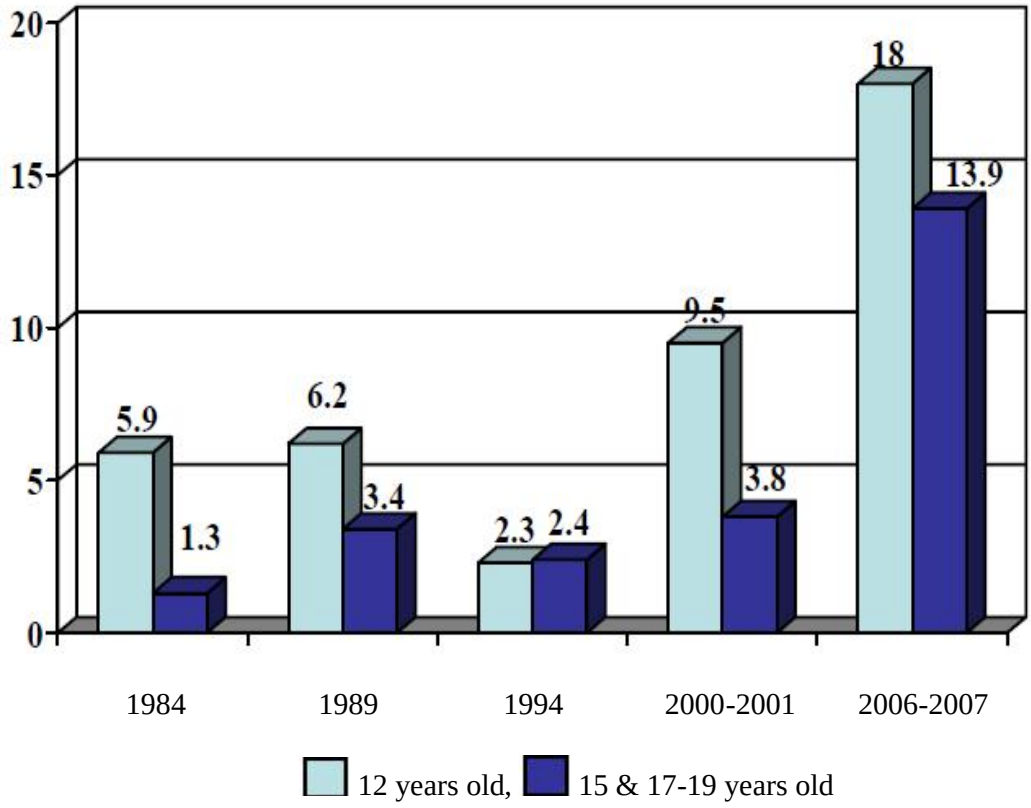


Figure 2.3: Percentages of adolescents with normal gingival condition from the National Dental Surveys in Thailand

(Source: Division of Dental Public Health, 2008: 38)

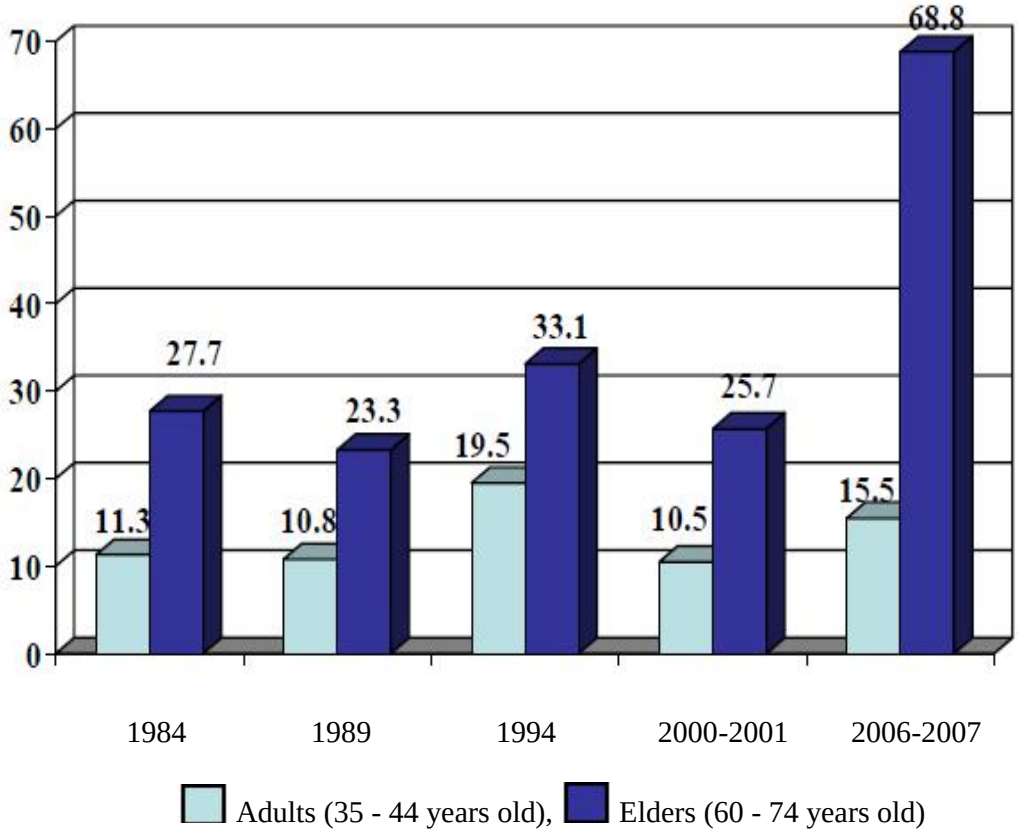


Figure 2.4: Percentages of adults and elders with presence of periodontal pocket of at least 6 mm depth from the National Dental Surveys in Thailand.

(Source: Division of Dental Public Health, 2008: 38)

(C) Tooth Loss

Secular trends of tooth loss in Thai adults (35-44 years old) and elders (60-74 years old) have been improving as indicated by increasing percentages of individuals with at least 20 functional remaining teeth in both age groups (see Figure 2.5). Nevertheless, these functional teeth are usually found to be affected by periodontal diseases. (Division of Dental Public Health, 2008: 36)

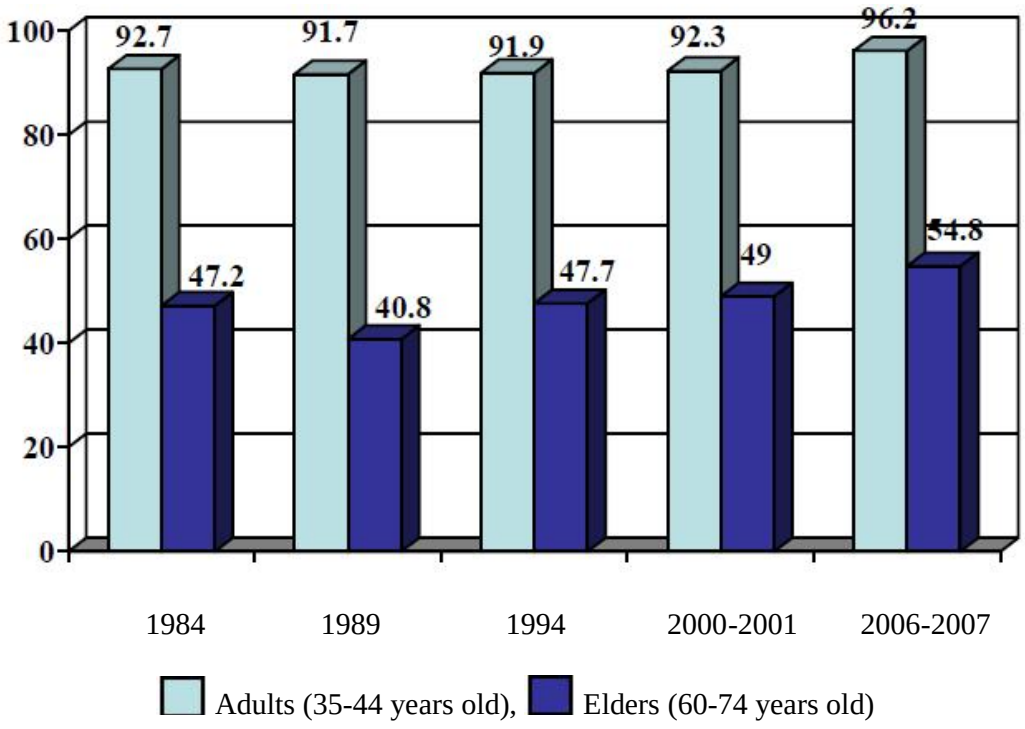


Figure 2.5: Percentages of adults (35-44 years old) and elders (60-74 years old) with ≥ 20 functional teeth from the National Dental Surveys in Thailand

(Source: Division of Dental Public Health, 2008: 37)

Regardless of the improving trends, tooth loss continues to be a major oral health problem in 82.84% of Thai adults (average loss = 3.92 teeth/person) and 94.04% of the elderly (average loss = 13.38 teeth/person) in the last survey. Total loss of teeth or edentulousness is also found in 10.47% of the elderly. (Division of Dental Public Health, 2008: 36)

Conclusion regarding oral health situation in Thailand

Dental caries continues to be the main oral health problem in deciduous teeth of Thai children as indicated by high DMFT values and great percentages of children with dental caries experience (Division of Dental Public Health, 2008: Executive summary). Although DMFT value of Thai 12-year-olds is found low in the last

survey, more than half of the adolescents still experience dental caries (Division of Dental Public Health, 2008: 35). As suggested by evidence that dental caries and its related consequences are the most common reasons for loss of permanent teeth among adults obtaining dental service free of charge (Akhter et al., 2008: 199-207), there is thus a need of long-term and practical dental preventive program in order to proactively prevent and control dental caries incidence early in childhood and adolescent ages.

Decreasing trend of tooth loss in Thai adults and elders can be observed especially in the last survey. However, retention of these remaining teeth has been extensively compromised by periodontal diseases. Severe periodontal diseases, as indicated by finding of periodontal pocket with at least 6 mm depth, are still prevalent in the elderly. Prevention and surveillance of poor periodontal condition leading to tooth loss should also be stressed in adults and elders. (Division of Dental Public Health, 2008: 36-38)

2.2 Oral Healthcare System in Thailand

(A) Organizational Structure

Oral healthcare provision in Thailand is based on a complex combination of providers. Dental services are offered by private providers, public hospitals under authority of Ministry of Public Health (MOPH), public providers of other government agencies and government corporations, and public-private partnership programs. (Waraporn Jirapongsa, Piyada Prasertsom, and Sunee Wongkhongkhathep, 2004: 17-23)

Private dental service providers – including private hospitals and grouped or single dental clinics – dominate oral healthcare provision especially in Bangkok (the national capital) and other urban areas in the country (Waraporn Jirapongsa et al., 2004: 21-22). Unlike other health professionals who mostly are public employees, up to 53.38% of dentists stay in the private sector (Gomes Wichawut, 2008: Online).

A number of public-private partnership programs for oral healthcare provision in Thai dental system have been initiated (Division of Dental Public Health, 2005: Online). A successful public-private partnership is the provision of basic dental services; including full-mouth scaling and polishing, dental extraction, dental filling, and dental prostheses; for beneficiaries of Social Security Scheme (SSS). Another example is the collaboration between dental units of public hospitals and private dental clinics or private hospitals to expand dental service provision for a large number of dental patients insured by UC. Another form of public-private partnership program is an oral health promotion and prevention program for school age children living in Bangkok. This program is unique in that funding organization and providers of the dental service are in different sectors. Funding is provided by National Health Security Office (NHSO), which is a government agency. However, the major providers of dental care, especially placement of dental sealant to prevent pit and fissure caries in children's first permanent molars, are private hospitals and clinics in Bangkok metropolitan areas. (Division of Dental Public Health, 2005: Online)

Apart from the private providers, there is a wide variety of public dental service providers. Some government agencies (e.g. Ministry of Defense) and government corporations (e.g. Electricity Generating Authority of Thailand, EGAT) possess their own dental units providing oral healthcare mainly for their personals.

Other government agencies; including both Department of Health and Department of Medical Services of the MOPH, Bangkok Metropolitan Administration (BMA), and municipalities; possess their own dental units as well but the provision of dental services is not only for their personals but also for general populations. Moreover, with an emphasis on academic purpose, university dental hospitals provide all levels of dental services – from primary to tertiary oral healthcare – also for general people. Above all, the most important providers of public dental services are multi-leveled public hospitals under authority of the MOPH, which has direct responsibility for the national oral healthcare provision. (Waraporn Jirapongsa et al., 2004: 23)

The purpose of establishing health facilities in all levels of administrative divisions in Thailand by the MOPH is to be the main provider of healthcare which can be accessed by local residents especially in the rural areas. In 1956, MOPH initiated regional extension of oral healthcare through successful establishment of provincial hospitals in all provinces. However, due to the fact that provincial hospital of each province is situated in an urban or urban-like area of the main district, barrier to dental care access still exists especially for residents of other rural districts. Since there is not another district hospital - which provides primary care - established in main district where provincial hospital is situated, then not only secondary and tertiary dental care is offered by the provincial hospital but also the primary dental care. Several provincial hospitals with comprehensive health facilities which meet a certain standard are later improved to become regional hospital (actually called ‘central hospital’). To further provide better access to dental care for a large number of populations living in rural districts nationwide, in 1975, dental public health section is initially established in district hospitals with the size of 30 beds and more. Later in

1982, the term ‘district hospital’ has been replaced by ‘community hospital’ and dental public health section is established in community hospitals of all sizes to provide primary and secondary dental care.* (Waraporn Jirapongsa et al., 2004: 18-19) About 32.4% of all dentists in Thailand are civil servants of MOPH and up to 55.37% of these employees work in district hospitals (Gomes Wichawut, 2008: Online). Before 2009, Community Health Centers were the main providers of primary healthcare at sub-district level. Primary dental services, with an emphasis on prevention and promotion of oral health for residents of local community, were provided mainly by dental nurses. (Waraporn Jirapongsa et al., 2004: 19-21) However, since 2009, these health centers have been improved in term of facilities to become sub-district health promoting hospitals (Bureau of Primary Care Development Coordination, 2012: Online).

The purposes of establishing these sub-district health promoting hospitals are to enhance equity and coverage of access to health facilities among local residents of all age groups, to provide prompt healthcare when needed, to alleviate severity of diseases, to decrease occurrences of preventable diseases, and to decrease overcrowding at district and provincial hospitals (Office of Permanent Secretary, MOPH, 2012: Online). Nevertheless, scope of dental services to be provided in the Sub-district Health Promoting Hospitals is still under process of development.

*****It is noted here that throughout this dissertation the term ‘district hospital’ is preferably used, instead of the term ‘community hospital’, when referring to hospital established at district level in Thailand in order to allow standard communication in public health field and to avoid misunderstanding with ‘community health center’.

These multi-leveled hospitals function collaboratively in the form of public hospital network and this enables referral of patients to hospitals with higher level of care. (Waraporn Jirapongsa et al., 2004: 51-52). At sub-district level, Sub-district Health Promoting Hospitals, which provide mainly primary healthcare, would also act as local screening units which can promptly make patient referral to nearby district or provincial hospitals (Office of Permanent Secretary, MOPH, 2012: Online). At district level, district hospitals function to provide primary and secondary care. When tertiary care is needed, referral can also be made upwardly to provincial or regional hospitals. Downward referral is also possible when higher level of care is no longer needed and local provider is capable of further patient management. (Waraporn Jirapongsa et al., 2004: 51-52)

(B) Oral Healthcare Financing Schemes

Service utilization at private dental providers in Thailand generally requires out-of-pocket payment, except for some public-private partnership programs. Nevertheless, public dental service is currently offered through various healthcare benefit schemes to allow better access to service for all Thai citizens (Thaworn Sakunphanit, 2006: Online). Implementation of UC in Thailand has been accomplished since 2002 in order to achieve full coverage of healthcare for Thai populations (Pongpisut Jongudomsuk, 2008: Online). Consequently, the majority of Thai people (76%) became UC beneficiaries and the rest of the populations are financially supported by other available benefit schemes; including Social Security Scheme (SSS) for 15%, Civil Servant Medical Benefit Scheme (CSMBS) for 7%, and other specific schemes (Thaworn Sakunphanit, 2006: Online). The other minor

schemes offering healthcare benefits are financially supported by Thai government to cover healthcare expenditure in some specific groups of employees; for instances, registered teachers of private schools and employees of government corporates (National Health Security Office, 2002: Online). The following Table 2.1 presents featured characteristics of major public healthcare benefit schemes in Thailand.

Beneficiaries of CSMBS (civil servants and their dependents) initially gain dental benefits through reimbursement of expenditure for each received dental service at eligible dental providers (Tewarit Somkotra and Palinee Detsomboonrat, 2009: 85-96). Online registration was later developed as a system to ease reimbursement of expenditure and self-provision of direct payment for received dental service prior to reimbursement was no longer needed.

SSS receives its funding from multiple sources including government funding, compulsory tax charge to formal sector private employers, and co-payment of their employees themselves. SSS offers dental benefits using capitation payment method. Dental benefits provided by SSS are restricted to routine dental services; including full-mouth scaling and polishing, dental extractions and dental fillings. (Tewarit Somkotra and Palinee Detsomboonrat, 2009: 85-96) Provision of removable acrylic dentures with constraint of only one reimbursement per every five years is also added to its dental benefits. SSS beneficiaries are required to initially pay for their received dental services either at public providers or collaborated private dental units. Then, these prepaid expenses can be reimbursed from the local SSS offices. Currently in 2012, SSS beneficiaries can reimburse their dental expenses for 300 Thai Bahts per received dental treatment and not exceed 600 Bahts a year.

Table 2.1: Characteristics of major public healthcare benefit schemes in Thailand

Characteristics	**Public Employees (Civil Servant Medical Benefits Scheme as a prototype)**	**Private Employees**		**The rest of Thai – Universal Healthcare Coverage Scheme (UC)**
		Social Security Scheme (SSS)	**Workmen's Compensation Scheme (WCS)**	
Scheme nature:	Fringe benefit*	Compulsory	Compulsory	Social welfare
Model:	Public reimbursement model	Public contracted model	Public reimbursement model	Public integrated model
Population coverage in 2006:	Civil servant of the central government, pensioners and their dependents (parents, spouse, children)	Formal sector private employee, > 1 worker establishment	Formal sector private employee, > 1 worker establishment	The rest Thai population, who are not qualified to previous columns
No. of Beneficiaries (million)	4.2	9.1	9.1 (same as SSS)	47

*****Fringe benefit is an employment benefit given additionally to salary or wages.

(Source: Thaworn Sakunphanit, 2006: Online)

A wide range of dental benefits supported by UC include dental filling, periodontal therapy, tooth extraction, surgical removal of impacted tooth, some other oral surgical interventions, dental sealant for children and adolescents aged under 15, pulpal therapy in deciduous tooth, obturator placement for children with cleft palate, and placement of removable acrylic denture once for every five years (Dental Council of Thailand, 2009: Online). In 2011, up to 47,996,600 UC beneficiaries (NHSO, 2011: 6) were enabled to utilize these public dental services for free.

(C) Provision of Public Dental Services in Thai District Hospitals

Since this dissertation focuses on public dental services provision in Thai district hospitals, this section is specifically devoted to additional explanation of the services in order to ease understanding in later discussions. In general, district hospitals are primarily established in rural districts in almost all provinces in Thailand, excluding the national capital (Bangkok) where public hospitals have been developed into general and central hospitals (equivalent to provincial and regional hospitals). There is no district hospital established in the main district of each province where provincial or regional hospital is situated. Some well-developed, urban-like districts outside the provincial main districts neither have district hospitals since they instead have general hospitals or even regional hospital (Haad Yai Hospital in Songkhla Province).

District hospitals have different sizes, ranging from 10 to 120 beds. Although the scopes of routine dental services are comparable among district hospitals regardless of the hospital sizes, larger district hospitals may additionally provide highly specialized dental care due to availability of dental specialists.

2.3 Provision of High-cost Dental Prosthetic Service

(A) Program Administration Prior to Establishment of National Dental Fund in Fiscal Year 2011

Provision of high-cost dental prosthetic service is distinct in method of financial administration. In general, routine dental benefits of UC – such as full-mouth scaling and polishing, dental filling, and dental extraction; are funded through pre-paid per capita budgeting system for outpatients. (Wirut Eungpoonsawat et al.,

2010: Online) In contrast, high-cost dental prosthetic service is financed through claim for reimbursement system. During service delivery, service expenses need to be initially covered by allocation from pre-paid per capita budget. After delivery of dental prosthetic service, local dental units then have to claim for service expenses from the central reimbursement fund of Bureau of Claim Administration, NHSO. (Bureau of Claim Administration, 2012: 41-43, 206-244)

The primary aims of using claim for reimbursement system for high-cost healthcare interventions are to allow patients' access to high-cost healthcare services at local hospitals, to promote rational use of healthcare budget, and to increase efficiency in healthcare resource use. Local dental units would obtain reimbursement of service expenses based on evidences of service delivery and real expenditure arises from service operation. During annual budgeting of reimbursement fund, NHSO would reserve three per cent of overall budget for late claim and appeal for reconsideration of claim. The rest of the budget would be used for reimbursement of claim that is made on time all year round. Reimbursement is made monthly (12 times a year) and amount of reimbursement in each time is adjusted to be comparable by anticipation based on previous records and information regarding demand of service, even though it would be varied by actual number of claim. (NHSO, 2011: 41-44)

Reimbursement of high-cost healthcare interventions are divided into three main categories including high-cost inpatient services (IP add on), high-cost outpatient services (OPHC), and high-cost instrument and prosthetic organs (Instrument: INST). High-cost dental prosthetic service is funded in the category of high-cost instrument and prosthetic organs and the service is further divided into four

categories (instrument codes) as summarized in Table 2.4. (Bureau of Claim Administration, 2012: 33-37)

Table 2.2: Categories of high-cost dental prosthetic service, indications of provision and corresponding standard prices

Instrument Codes	Categories of Dental Prostheses, Characteristics and Indications of Use	Unit	Standard Price Estimates (THB)
9202	**Single denture:** - Removable acrylic complete denture for either maxillary or mandibular dental arch - Use for replacement of total tooth loss in single dental arch to restore masticatory function	Piece	2,400
9203	**Complete denture:** - Removable acrylic complete dentures for both maxillary and mandibular dental arches - Use for replacement of total tooth loss in both dental arches to completely restore masticatory function	Set (= 2 Pieces)	4,400
9204	**Partial denture with 1-5 replaced teeth:** - Removable acrylic partial denture with 1-5 artificial teeth in single dental arch - Use for partial replacement of 1-5 teeth In single dental arch to restore masticatory function	Piece	1,300
9205	**Partial denture with > 5 replaced teeth:** - Removable acrylic partial denture with more than 5 artificial teeth replacement in single dental arch - Use for partial replacement of more than 5 teeth in single dental arch to restore masticatory function	Piece	1,500

(Source: Bureau of Claim Administration, 2012: 242-243)

Claim for expenses arise from provision of high-cost dental prosthetic service in general circumstance is defined as the claim under category of high-cost instrument and prosthetic organs and the claimed expenses for a certain type of dental prosthesis do not exceed the corresponding standard price estimate announced in appendix section of Manual of Claim for Health Service Expenses (see also in Table 2.4). Nevertheless, the announced standard price estimates for the dental prosthetic services are used as guideline for management of service expenses. This means that the real expenses arise from service provision may not be necessarily lower or equal to the announced estimates. For instance, some dental units or hospitals – such as those situated on islands – may be very far away from the dental laboratories which are responsible for laboratory process of denture fabrication. In such a case, excessive expense of service provision may be due to additional logistic cost of service production. Consequently, reimbursement can be made higher in value compared to that of standard price estimate based on evidence of greater expenditure. (Bureau of Claim Administration, 2012: 33-37)

General regulation of claim for dental prosthetic service expenses is as followed (Bureau of Claim Administration, 2012: Introductory section):

a) Claim documentation:

- Record of diagnostic code is based on coding system of International Statistical Classification of Diseases and Related Health Problems 10th Revision Version for 2007 or WHO ICD-10 2007 version. It should be noted that after official use of Diagnosis Related Group – version 5.0 (DRG V5), WHO ICD-10 2010 version has been instead adopted since the First of October, 2011.

- Record of procedure code is based on coding system of International Classification of Disease 9th Revision Clinical Modification 2007 or WHO ICD-9-CM 2007 version. It should also be remarked that after official use of DRG V5, WHO ICD-9-CM 2010 version has been instead adopted since the First of October, 2011.

- Calculation of service expenses is based on the criteria of NHSO's 18 Standard Categories of Healthcare Expenses.

b) Delivery of claim documents:

- Service providers need to deliver claim documents via 'E-Claim' system, based on format and method specified by NHSO. Evidences of service expenditure in hard copy format should be prepared and kept at the service unit for documentation audit.

- If the evidences of service expenditure in hard copy are proved lacking during documentation audit by NHSO personals, the service unit will need to pay back the reimbursement.

c) Time frame for delivery of claim documents:

- Service providers need to deliver the claim documents within 30 days from complete service delivery for outpatients. NHSO specifies accounting period in monthly pattern.

d) Reimbursement in case of late delivery of claim documents:

- Reimbursement would be discounted in different rates as followed:

Case I – Late claim within 30 days after regular claim period, 95 per cent of normal reimbursement would be paid.

Case II – Late claim within 60 days after regular claim period, 90 per cent of normal reimbursement would be paid.

Case III – Late claim within 330 days after regular claim period, less than or equal to 80 per cent of normal reimbursement would be paid – depending on remaining reserved global budget for late claims and claim appeal.

e) Correction of claim documentation and claim appeal:

- Service providers can correct the claim documents already sent via E-Claim in two periods.

- The first period for correction is before the end of accounting period in each month. Erroneous documentation – such as missing out on some cost items, wrong expenditure calculation, and others – can be corrected before reimbursement is paid.

- The other period for correction is regarded as 'claim appeal' period which is the time when previously-sent documents have already been considered at the end of a certain accounting period and the reimbursement has been paid to the service unit. Appeal can be made for reconsideration of claim.

(B) Program Administration by National Dental Fund in Fiscal Year 2011

Even though routine dental interventions – such as scaling, dental filling, dental extraction, and others - have been financially supported by UC and dominantly provided in public dental setting; burden of oral diseases has not been decreased and problem in access of public dental service especially in rural areas still markedly exists. Therefore, in fiscal year 2011, administrative board of NHSO has approved establishment of National Dental Fund to focus on control of existing oral disease prevalence and prevention of new occurrence in specific target groups of populations

– such as primary school children and pregnant women. (Wirut Eungpoonsawat et al., 2010: Online)

In the aspect of budget administration in fiscal year 2011, National Dental Fund gained its budget from per capita budget (39.25 THB per registered UC beneficiary) and allocated its budget into two main parts – including oral health prevention and promotion, and dental prosthetic service. Framework for National Dental Fund's budget administration is shown in Figure 2.6. (Wirut Eungpoonsawat et al., 2010: Online)

Although the previous claim and reimbursement administration system for dental prosthetic service is still adopted onward, the markedly difference in terms of budgeting after the establishment of National Dental Fund exists in that the budget for dental prosthetic service is better defined and more production of service is anticipated compared to the budget previously included in central reimbursement fund with neither specific allocation proportion nor clear anticipation of service production.

2.4 Overview of Efficiency Issues in Healthcare Service Provision

(A) Performance Measurement in Healthcare Service Provision

Firms are production units which act to change production inputs into outputs– including goods and services. An instance of firm in healthcare industry can be a hospital which utilizes materials (e.g. medicine), capital (e.g. hospital building) and labor (e.g. health personals) to produce outputs (e.g. health services). Performance of a certain firm can have a wide variety of definition. Thus, to measure performance of healthcare firms, as well as other types of firms in other industries, several methods

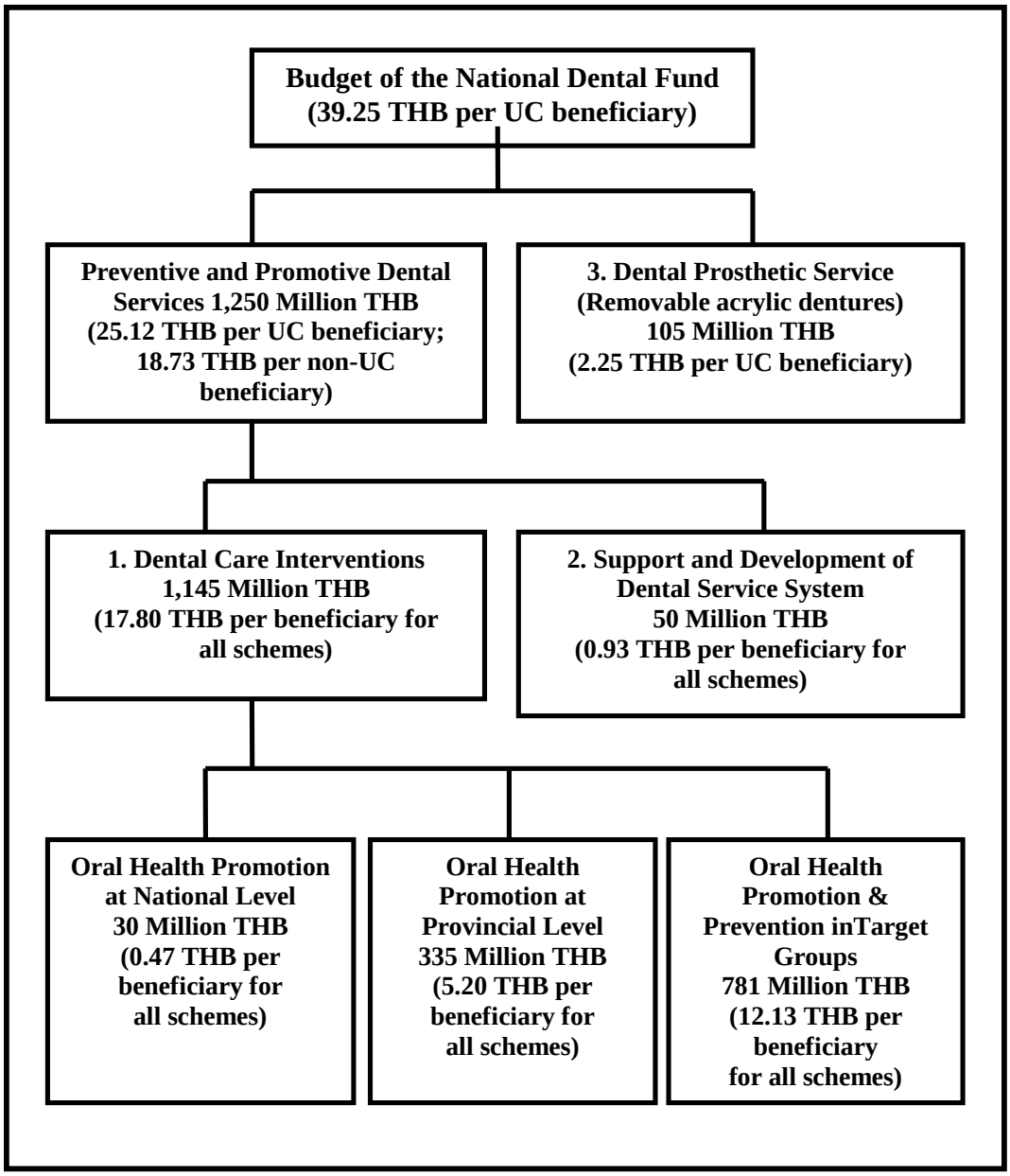


Figure 2.6: Framework for National Dental Fund's budget administration in fiscal year 2011

(Source: Wirut Eungpoonsawat et al., 2010: Online)

can be applied based on definitions of performance. The simplest form of performance measurement is productivity ratio or the ratio between quantities of production outputs to production inputs. The greater values of the ratio would imply higher quality of performance. Since measuring performance of firm needs comparator or standard to gauge whether the firm is operating at the optimal level of production or the best practice standard, relative concept is always needed to be applied. This means that performance of a certain firm could be either measured relative to itself at different time periods or to another firm at the same time period. For example, production of a certain medical service by a hospital in 2011 could be measured relative to such production of the same hospital in the previous year of 2010 or its performance could also be measured in comparison to production of such service produced by another hospital in the same year of 2011. (Coelli et al., 2005: 1-5)

The other approach of performance measurement is efficiency analysis which concerns about relationship between resource use in production process and output produced. Efficiency is an important issue in running health system under constraint of limited health resource in order to maximize utility of such resource use (Jiruth Sriratanaban, 2000: 1-2).

In general, economics or study of rational choice is concerned with the process by which a person or society has make decision regarding use of scarce resource to produce goods and services that would be allocated to serve members of the society. When this concept is applied in the field of health and healthcare, it is regarded as health economics which concerns about allocation of scarce health resources in different alternatives of healthcare. The basic issue that society needs to face is the

scarcity of resource which implies that resource is not adequate to serve all needs and neither to satisfy each and every member of the society. When resource is decided to be allocated to an alternative of goods or service production, such resource can no longer be available for other production choices. The value of benefit or output which can be obtained from the forgone alternative is considered as cost of such resource use. This cost is regarded as opportunity cost. Since resource is scarce and all decisions regarding resource use have corresponding opportunity cost, production of goods or services from such resource use should thus yield maximum outputs or utility. This notion becomes definition of efficiency. (Jiruth Sriratanaban, 2000: 1-2; Nakhun Thoraneenitityan, 2007: xv)

(B) Market Mechanism and Exceptional Features of Health System From Economic Viewpoint

Understanding market mechanism is important for further explanation regarding efficiency from economic viewpoint. In well-functioning market, production of goods and services has technical efficiency (producing goods and services at lowest cost of production), cost effectiveness (producing goods and services in well-proportionated manner), and allocative efficiency (allocation of produced goods and services which reflects ability and willingness to pay). Price plays a crucial role in both production and consumption. Price is a determinant of which goods and services would be produced and in what production amount. Price also indicates allocation of produced goods and services to consumers with highest ability and willingness to pay. In other words, each consumer needs to decide which goods and services to be consumed based on selling price and personal income. The

role of price is even accentuated when no policy or measure exists to compensate inability to pay. Price then determines quantities of both demand and supply of goods and services in the market. (Jiruth Sriratanaban, 2000: 2-3)

However, health system is unique and different from other types of firms or industries in various ways and cautious consideration regarding efficiency of health system is needed – especially exceptional features which violate general characteristics of the mentioned well-functioning market. The eight exceptional features of health system include uncertainty, information asymmetry, derived demand, roles of not-for-profit organizations, role of social needs, government subsidy, health insurance, and restriction of competition. From economic viewpoint, these features of healthcare system cause market failure or distort price mechanism and consequently affect decision on what to be produced and how to allocate the produced goods and services. This ultimately gives rise to inefficiency, inequality, and need of additional cost of production. These features are explained in details as followed (Coelli et al., 2005: 172; Jiruth Sriratanaban, 2000: 9-12):

a) Uncertainty:

Uncertainty in health system exists in both demand and supply of healthcare. On the demand side, disease occurrence and accident which need healthcare cannot be exactly predicted. On the other hand, outcomes of healthcare interventions are neither ensured. Therefore, individual's need of healthcare and related cost seem to be unpredictable. Consequently, decision regarding health and healthcare is well grounded on risk. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

b) Information asymmetry:

Patients or health service users usually have limitation regarding knowledge of health and self-care. For instance, patients can neither diagnose their diseases nor prescribe appropriate treatment modalities by themselves. In contrast, service providers possess professional knowledge and play dominant roles in making diagnosis of health condition, prescribing appropriate healthcare interventions, and offering relevant health information. This imbalance or inequality of knowledge between health service users and providers is regarded as health information asymmetry. The information asymmetry causes market failure by the fact that service providers have more market power. This condition gives rise to supply-induced demand or demand for healthcare that is influenced by healthcare suppliers. To alleviate the problem of supply-induced demand, measures – such as professional healthcare licensure, professional ethics and regulations – are thus adopted in health service provision. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

c) Derived demand for healthcare:

Every individual actually want to be healthy, consequently the individual would seek for healthcare intervention which is believed to create health. Therefore, demand for healthcare does not occur by itself but rather as a result of the real demand for health. This phenomenon is regarded as derived demand for healthcare. Although the demand for healthcare appears to be associated with demand for health, such relationship is not a one-on-one or directly-proportionated association. Neither the two terms can be used interchangeably. The notion can be explained by two underlying reasons. Firstly, healthcare is only an alternative to restore or maintain health. In many cases, other options or measures – such as environmental

conservation – may be more efficient in maintaining health than healthcare intervention. The other reason is that demand for healthcare depends significantly on expectation whether the healthcare intervention is potential to result in positive health outcome. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

d) Roles of not-for-profit organizations:

In general, business firms operate with aim of maximizing profit gain and this affects firms' behavior in comparing prices and costs of production. In contrast, some healthcare providers operate as not-for-profit organizations and economic behavior becomes inconsistent with market mechanism since costs of production and efficiency may not be important issues in operation. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

e) Role of social needs:

Personal healthcare not only affects personal health condition but also affects health of others or having external effects on others. The external effects can be either external costs or external benefits. The external benefits become important features enabling health system to function in serving social health. The external benefits can be characterized in three ways. Firstly, personal health benefit can be gained from healthcare of others. For instance, an individual would gain benefit of lower risk in catching a certain contagious disease when other people receive vaccination preventing such infection. The benefits of this kind are regarded as selfishly-based external benefits. Secondly, since people can realize that health care would serve need of being healthy for the whole society and all individuals would mutually gain health benefits, then people would encourage one another to receive appropriate healthcare interventions. This second external benefits is thus regarded as paternalistically-based

external benefits. The other external benefits arise when the benefits of others or the whole society are the major aims instead of an individual's benefit. Such external benefits are altruistically-based external benefits. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

f) Government subsidy:

In all countries worldwide, government of each country would provide financial support in some ways to health system. In many cases, many governments even take the role of major healthcare providers to publicly serve their populations. Such crucial role would tremendously affect the function of market mechanism, restriction or promotion of competition and production efficiency and the way that healthcare commodities and services would be allocated. (Coelli et al., 2005: 172; Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

g) Health insurance:

Health insurance enables service utilization with less concern regarding out-of-pocket payment. As a result, influence of price on equilibrium between demand and supply of healthcare is decreased. This is due to the fact that health insurance not only influences demand of healthcare but also induces healthcare providers in some ways. For instance, health benefits covered under health insurance would affect selection of treatment modalities or even some interventions which are costly. (Goodman, Stano, Folland, 2012; Jiruth Sriratanaban, 2000: 9-12)

h) Restrictions of competition:

Competition in healthcare market among healthcare providers could be restricted by policies, measures, and regulations of the government. As a result, market mechanism cannot fully function and efficiency regarding production of

healthcare commodities and services is also downgraded. Restrictions of competition can be in various ways such as healthcare professional licensure, restriction on advertisement and public relation, ethical codes of healthcare professions which control behavior of health personals. Although these measures are importantly needed to maintain standard and equity of healthcare, the measures also decrease competition within market and consequently result in additional cost burden to the whole society. (Coelli et al., 2005: 172; Jiruth Sriratanaban, 2000: 9-12)

(C) Relationship between Quality and Efficiency in Health System

There are four main components of quality in health system including customer satisfaction, right the first time, standards, and quality of life. Health system should function to provide customer or patient satisfaction since it reflects whether the system responds well to the need of health. Right the first time implies that health system should function with no defect (zero defect) and healthcare provision should be right from the start since any error occurred can be harmful to human life in some ways. Healthcare provision should also meet standards including professional standards, practice protocols, and moral and ethics. Ultimately, health system should function to create quality of life – not only create disease-free condition. (Jiruth Sriratanaban, 2000: 17-18)

Quality and efficiency in health system are closely related in two-ways pattern. Provision of healthcare with consideration of high quality would result in efficiency of health resource use. On the other hand, health system design which aim of efficiency would also create quality of healthcare. Thus, the relationship among the four components of healthcare quality and three components of healthcare efficiency can be illustrated as in Figure 2.7. It should be noted that technical efficiency is

related to the most number of components in healthcare quality including right the first time, standards, and quality of life. In hospitals with compromised quality of hospital administration and health service provision, inefficiency exists in various aspects – for instances; the disproportion between number of personals and real workload, inadequacy of instruments, absence of maintenance system, incompetence of personals on effective use of healthcare materials and equipment, and uneconomical use of energy. Then, a crucial question concerning efficiency in health system is that to what extent of efficiency improvement, cost minimization, and enhancement of healthcare quality should be invested. (Jiruth Sriratanaban, 2000: 17-18)

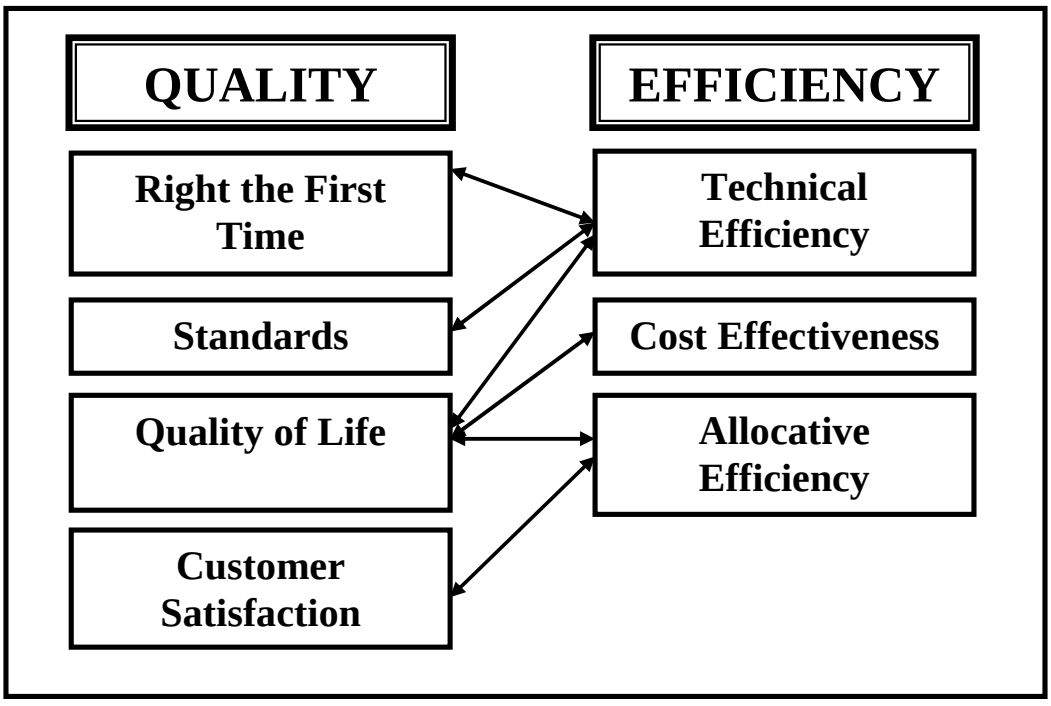


Figure 2.7: Relationship among components of healthcare quality and efficiency

(Source: Jiruth Sriratanaban, 2000: 17)

CHAPTER III

DATA ENVELOPMENT ANALYSIS:

THEORETICAL FRAMEWORK AND APPLICATION IN

DENTAL SERVICE

This chapter is devoted to explaining basics of data envelopment analysis (DEA) and review of its applications in dental service delivery. This chapter is organized into three main parts. The first part elucidates the concept of performance measurement, definitions of some related terms–especially 'productivity' and 'efficiency', distinction between productivity and efficiency, and applicable methods of measuring relative efficiency of firms. The second part emphasizes on detail of DEA. In this part, non-parametric approach in estimation of frontier function and computation of efficiency score is explained. Basic input- and output-oriented DEA models under assumption of variable returns to scale are critically discussed due to applicability in measuring efficiency of dental service delivery. Input- and output-oriented DEA models under constant returns to scale assumption are as well mentioned. The final part of this chapter reviews previous literature regarding application of DEA to efficiency measurement in dental service delivery.

3.1 Performance Measurement in Healthcare

(A) Overview of Performance Measurement

Performance measurement in healthcare can be defined variously. The term can be defined as a mechanism for measuring both healthcare quality and cost of care (Garrett, 2007: Online). Adair and colleagues define that performance measurement is

a four-step process–involving conception and plan for action, selection and development of measures, data collection and analysis, and report and utilization of results–which can take place at any levels of systems and organizations (Adair et al., 2006: 87-88). Nonetheless, performance measurement which is of relevance to the context of analysis in this dissertation would be basically defined as a study of capability of an entity in transforming production inputs into production outputs or products using a certain technology in production process. In other words, regarding healthcare provision, performance in this context is 'productive performance' of healthcare organizations (e.g. hospitals) in producing or delivering healthcare service.

An entity utilizing inputs to produce outputs is generally called productive 'firm' (Coelli et al., 2005: 1). Therefore, hospitals, for instance, can be considered as firms which utilize health resource inputs–including materials (e.g. drugs), labor (e.g. doctors), and capital (e.g. operating rooms)–to outputs such as healthcare service. It should be noted that a term 'decision making unit' (DMU) can also be widely found in literature related to performance measurement and this term is ungainly used instead of 'firm' when considering smaller units which are actually parts of a whole firm (Coelli et al., 2005: 1). For instance, when operation of different provincial branches of a certain private insurance company is compared, each provincial branch can be viewed as a DMU in the whole firm of the company. Throughout this dissertation, the term 'firm' is used to refer to a certain dental unit or district hospital of analysis due to more general definition.

Performance measurement adopts a relative concept which means that performance of a certain firm can be assessed either by comparing to itself at different

periods of time or comparing to other firms using the same production technology at the same period of time (Coelli et al., 2005: 1).

A simple method of performance measurement is ratio of productivity calculation. Productivity is a ratio between quantity of outputs and quantity of production inputs in production process. In general, the greater value of the ratio implies better performance. When the value of ratio exceeds one, this would imply productivity progress. In contrast, when the value of the ratio is less than one, this would contrastively imply productivity regress. Calculation of productivity ratio can be easily achieved when production involves only limited number of production inputs and outputs. However, in case of multiple inputs and outputs production process, calculation of such ratio can be much more complicated and this involves combination of multiple inputs into a single value of index number (input index) as well as index number of multiple outputs (output index) before putting these index numbers into ratio. This measure of productivity would imply 'total factor productivity' (TPF)–meaning that all multiple inputs and multiple outputs involved in a certain production are taken into account for the calculation of productivity ratio. (Coelli et al., 2005: 1-3) Theoretical examples of productivity ratio calculation using index numbers are illustrated in the following Table 3.1 and 3.2. In some literature concerning productivity analysis; a number of terms including 'labor productivity', 'land productivity', and 'fuel productivity' can also be found. These terms are actually partial measures of productivity since only one or some production inputs or outputs are taken into consideration in calculation of productivity ratio. Consequently, unlike 'total factor productivity', 'partial productivity' can potentially be a misleading measure of overall productivity. (Coelli et al., 2005: 1-3)

Table 3.1: Calculation of productivity ratio using input index: a case of comparing two healthcare firms using three production inputs to produce a single output of healthcare service in a certain year

Firm	Output (y)	Input 1 (x_1)	Input 2 (x_2)	Input 3 (x_3)	Input index (x)	Productivity ratio (y/x)
A	160	70	30	20	(1/3)(70+30+20) = 40	160/40 = 4
B	150	90	20	40	(1/3)(90+20+40) = 50	150/50 = 3

Note: Assuming that all 3 production inputs are equally important for production of the output, input index is thus obtained by summation of these 3 inputs multiplied by 1/3.

Table 3.2: Calculation of productivity ratio using both input index and output index: a case of comparing two healthcare firms using three production inputs to produce two outputs in a certain year

Firm	y_1	y_2	x_1	x_2	x_3	y	x	y/x
A	160	140	55	45	50	(1/2)(160+140) = 150	(1/3)(55+45+50) = 50	150/50 = 3
B	150	170	45	20	55	(1/2)(150+170) = 160	(1/3)(45+20+55) = 40	160/40 = 4

Note: y_1 = output 1, y_2 = output 2, x_1 = input 1, x_2 = input 2, x_3 = input 3, y = output index, x = input index, y/x = productivity ratio. In this example, like the previous example in Table 3.1, all 3 inputs are assumed to be equally important in production process and input index is calculated in the same way. This assumption also extends to the 2 outputs and thus output index is obtained by summation of 2 outputs multiplied by 1/2.

Apart from calculation of productivity ratio calculation, another alternative approach of performance measurement is efficiency analysis. The most commonly applied techniques of efficiency analysis are DEA and stochastic frontier analysis (SFA). These techniques are usually adopted for analysis of data from sample of firms to obtain measures of relative efficiency among the firms analyzed in these models. (Coelli et al., 2005: 6)

(B) Distinction between Productivity and Efficiency

In general, the term ‘productivity’ and ‘efficiency’ seem to be used interchangeably. However, based on concept of production economics, these two terms are not the same things. Unlike ‘productivity’ which is simply calculated in term of ratio between output and input, efficiency of firm can be measured from production frontier. (Coelli et al., 2005: 3-4) To clarify this concept of ‘technical efficiency’, a production process with single input and single output is illustrated in Figure 3.1 as an example.

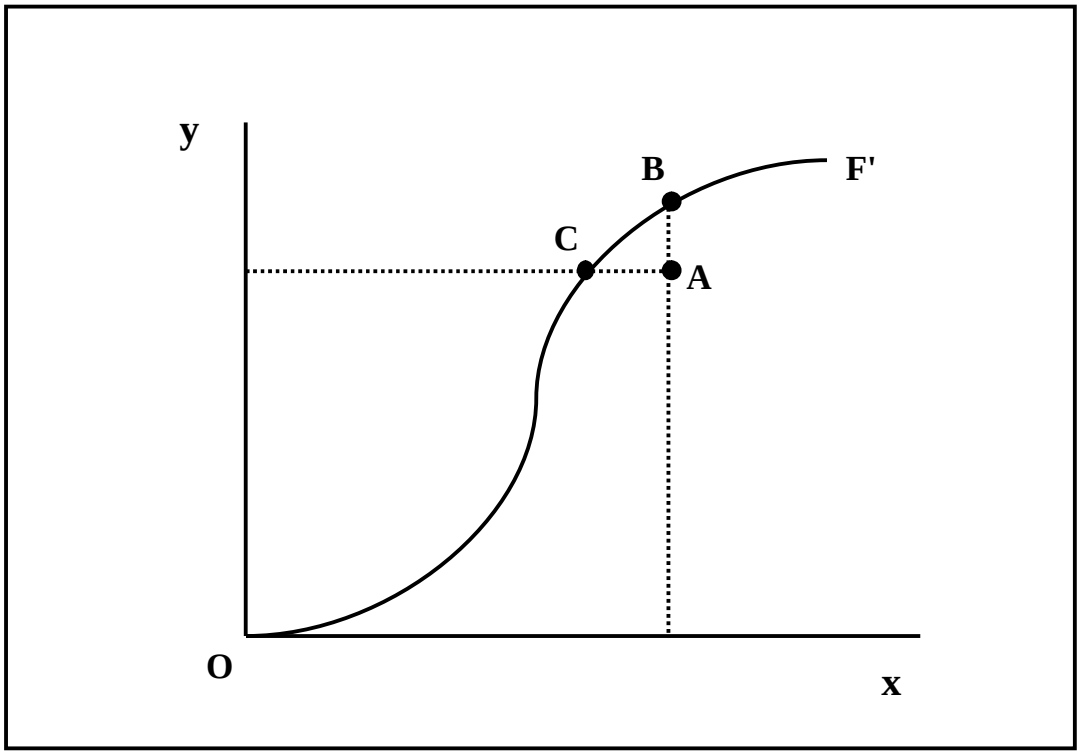


Figure 3.1: Production frontier of single input and single output production

(Source: Coelli et al., 2005: 4)

Figure 3.1 illustrates single input (x) and single output (y) of three firms (A, B, and C). The OF' line is production frontier. Production of firm A is under the

production frontier while other two firms (B and C) are operating on the frontier line. This illustrates that production undertaken by firm B and firm C has technical efficiency while production of firm A still has technical inefficiency. In this case, technical efficiency score for firm A can be determined by ratios of distances OA/OB or OC/OA – which are measured from point of origin (O), and such efficiency score is less than one implying existence of technical inefficiency. (Coelli et al., 2005: 4)

The following Figure 3.2 further illustrates difference between productivity and technical efficiency by adding rays drawn from point of origin (O) to the point where the three firms are operating. Considering different slopes of three rays drawn from the origin, the ray OC has the largest slope or the greatest value of $\Delta y/\Delta x$ which implies ratio of productivity. In other words, firm C has highest productivity compared to firm A and B. Now the difference between productivity and technical efficiency can be clarified that even though both firm B and C have technical efficiency as mentioned before, the productivity of these two firms are not equal as illustrated by difference in slope. Thus, two firms which are operating on technical frontier or having technical efficiency do not imply that these firms have the same ratio of productivity. In this case, Firm C also shows that it has technically optimal scale or it is operating at the optimal size of firm enabling efficient use of production input to yield highest quantity of output (scale economies). Conclusively, firms operating on technical efficiency frontier are technically efficient but their productivity may be improved by exploiting scale economies–or either by up-sizing or down-sizing. Nonetheless, modifying operational scale of the firm may not be practically achieved in a short period of time. (Coelli et al., 2005: 4-5)

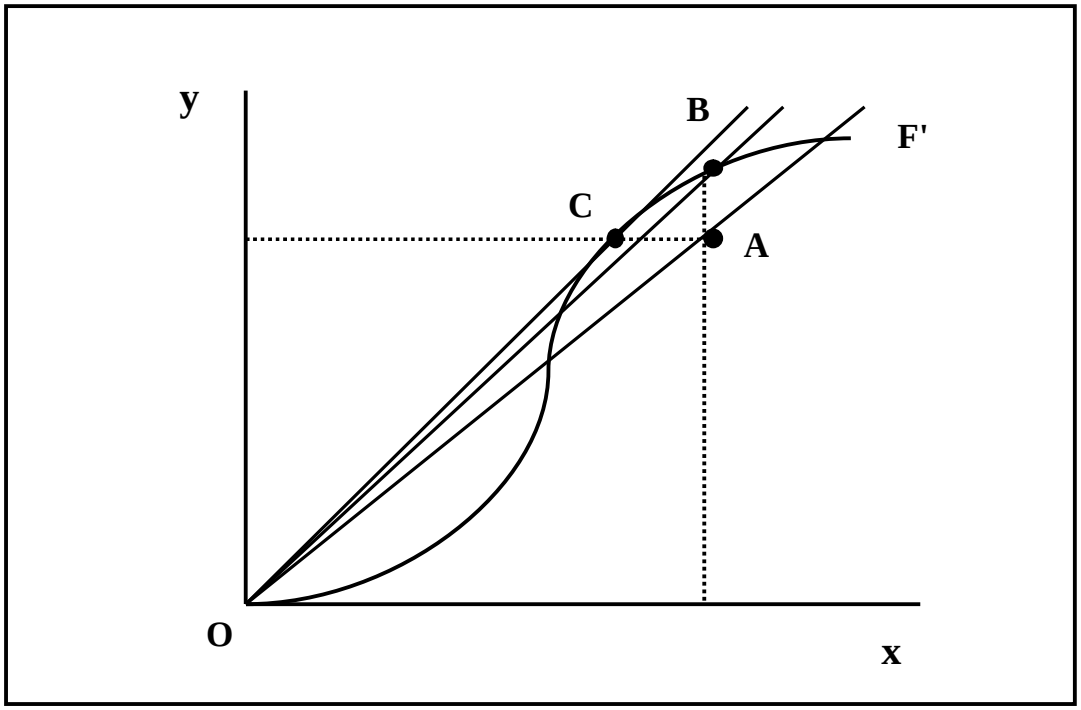


Figure 3.2: Production frontier of single input and single output production for illustration of difference between productivity and technical efficiency

(Source: Coelli et al., 2005: 5)

(C) Efficiency Analysis Techniques

Modern approach of firm-level efficiency measurement has been initiated by Farrell (1957). In general, efficiency in production economics usually refers to optimal use of resources to produce goods and services. Farrell defined that being technically efficient can be either producing the greatest amount of production output given a certain extent of input, or producing a certain quantity of production output using minimal amount of production inputs. (Farrell, 1957: 253-281 cited in Hollingsworth, Dawson and Maniadakis, 1999: 161)

Farrell illustrated the concept of technical efficiency measurement by considering an operation of a firm using two inputs (x_1 and x_2) to produce a single output (y) with constant returns to scale (CRTS) assumption. The concept was depicted as shown in the following Figure 3.3.

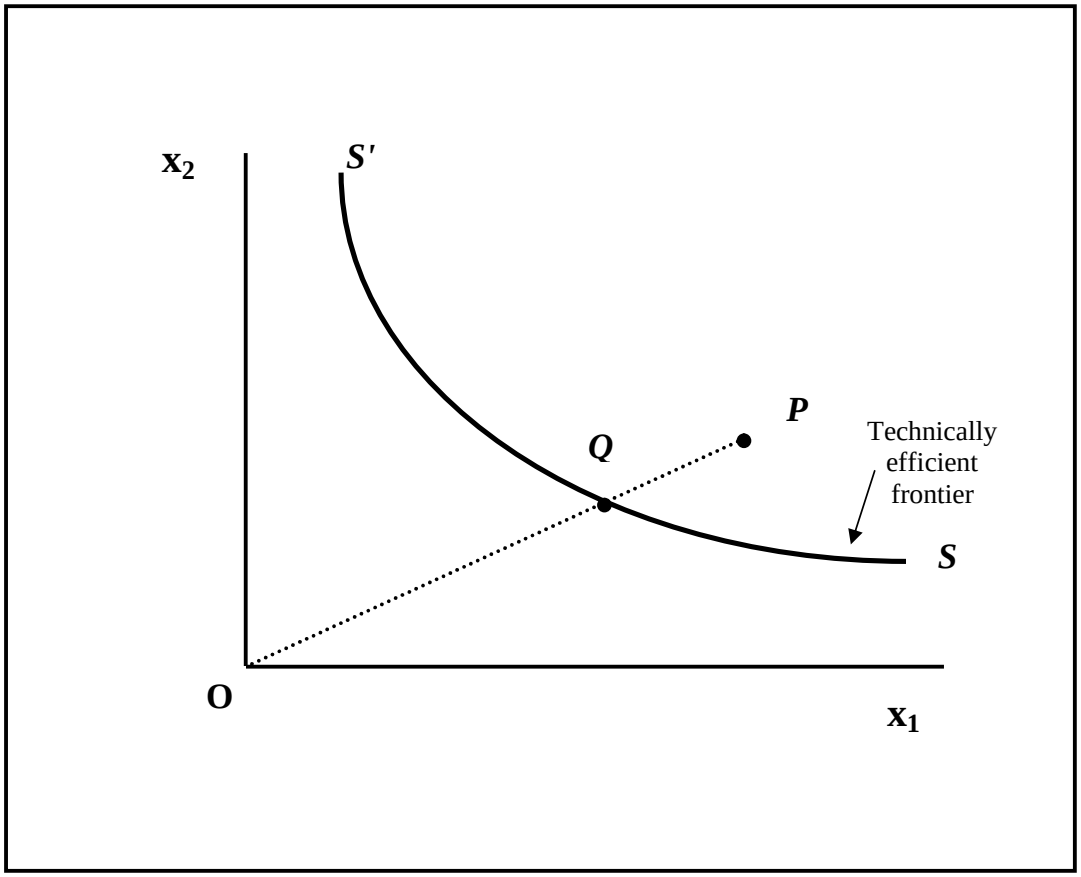


Figure 3.3: Farrell's measures of technical efficiency

(Source: Nakhun Thoraneenitityan, 2007: 20)

According to Figure 3.3, the firm under consideration uses two inputs of x_1 and x_2 at level of point P to produce a certain amount of the output (y). Technically efficient frontier is structured by the most efficient firms of all sampled firms taken into

consideration. The efficient firms operating on the input-oriented technical efficiency frontier in this example are those use the least possible amount of inputs to produce a certain amount of production output. Technical efficiency (TE) can then be measured by ratio between the distance of OQ and that of OP (TE = OQ/OP). Distance of PQ indicates technical inefficiency. (Nakhun Thoraneenitityan, 2007: 19-21)

Two principal methods of frontier estimation for relative efficiency measurement in a sample of firms are DEA and SFA (Coelli et al., 2005: 6). These two data-oriented approaches of frontier estimation are very useful for more complicated efficiency measurement when multiple inputs and multiple outputs are taken into consideration. These two methods differ in two main ways: whether functional form for estimated frontier is presumably specified, and whether random error is taken into account for deviation of a certain firm from operation on the efficiency frontier. SFA is a parametric frontier estimation method which presumes a certain function form of the frontier. SFA also assumes that random error can potentially contribute to inefficiency of firm's operation. In contrast, DEA is a non-parametric frontier estimation approach which does not require assumption concerning functional form of the estimated frontier. DEA is also a deterministic approach which assumes that deviation of a firm from the efficient frontier is due to inefficiency. (Hollingsworth, Dawson, and Maniadakis, 1999: 163)

It has long been controversial about which frontier estimation method is better between DEA and SFA. Mortimer has conducted a systematic review to compare advantages and disadvantages of DEA and SFA together with the distribution free analysis (DFA). It has been revealed that none of the selected articles in the

systematic review can confirm apparent dominance of one technique over its encounter. (Mortimer, 2002: 136 cited in Simaba and Haghifama, 2011: 1204)

(D) Efficiency Measurement Method in this Dissertation

For efficiency analysis of high-cost dental prosthetic service–involving multiple inputs (e.g. dentists and dental materials) and multiple outputs (various types of dental prostheses)–in this dissertation, DEA is selected as an efficiency measurement approach due to the following important reasons.

a) DEA can be simply applied for analysis of production using multiple inputs to produce multiple outputs. This feature of DEA makes it applicable especially for efficiency measurement in health care service provision; which generally involves input of heterogeneous health professionals with various expertise, a wide variety of materials and instruments and other supplies for production of multiple categories of healthcare interventions. (Hollingsworth et al., 1999: 163)

b) There is no need of assumption regarding functional form of production technology when DEA is adopted as analytical approach. As a matter of fact, true functional form of production technology is usually unknown. Consequently, imposition of parametric functional form for production technology required in parametric approach of efficiency analysis may lead to some degree of error in the obtained measure of efficiency. (Hollingsworth et al., 1999: 163)

c) DEA does not require any prior knowledge concerning weights of inputs and outputs. Since, as earlier mentioned, production of healthcare service usually involves multiple service production inputs and outputs, assigning numerous weights to all involved inputs and outputs can be very problematic and far too complex to be

rationally achieved. Moreover, justification of the assigned weights to the inputs and outputs can also be controversial. For example, it would be very hard to rationally say that fabrication of a certain kind of denture is two times more requiring or difficult than production of another category of denture. DEA overcomes this problem by using variable weights directly obtained from data. Consequently, making a number of assumptions and excessively complicated computations regarding fixed weight options are therefore avoidable. (Cooper, Seiford, and Tone, 2007: 12-13)

d) Unlike parametric approach of efficiency measurement which tries to centrally fit a regression plane though the observations, DEA instead constructs efficiency frontier by floating a piece-wise linear-segmented surface to envelope over the whole data. Consequently, skewness of data does not critically affect validity of efficiency measures as much as in parametric efficiency analysis. (Nakhun Thoraneenitiyan, 2007: 12-13)

e) DEA has proved to be a rational and applicable choice of efficiency measurement method to assess performance of healthcare organization in providing healthcare service. Practical applications of DEA in efficiency measurement of health care are indicated by many previous studies which have successfully applied the method to various contexts of healthcare service provision. Consequently, unlike parametric approach of efficiency analysis which has seldom been applied, DEA has a prominent role in the literature regarding performance measurement in healthcare service. (Hollingsworth et al., 1999: 163)

Since DEA is the selected efficiency analysis approach in this dissertation, next section of this chapter is thus devoted to explanation in more details about the DEA model.

3.2 Non-parametric Frontier Approach in Efficiency Analysis: DEA

(A) Overview of the Technique

Early development of DEA was undertaken by Charnes, Cooper and Rhodes in early 1970s (Cooper, Seiford, and Zhu, 2004: 4). Following their publication concerning present form of DEA in 1978, DEA has received great attention since then and its extensive applications have well dominated the literature regarding performance measurement (Coelli, 1996: 10), especially in efficiency analysis of healthcare service (Hollingsworth et al., 1999: 163).

DEA is a non-parametric, mathematical linear programing technique used to identify production frontier by means of enclosing all data like an envelope. The efficiency frontier is structured by the set of best-practice firms above all other considered firms. (Coelli, 1996: 9) These best-practice firms are those for which no other firms or linear combinations of other firms can produce as much or more amount of all production outputs or utilize as small or less amount of all production inputs. Efficiency score of each firm would be calculated through solving mathematical linear programming problems. (Coelli et al., 2005: 163)

DEA models can be categorized by assumptions of production technology into constant returns to scale DEA model (CRS DEA model) and variable returns to scale DEA model (VRS DEA model). DEA models can also be categorized by orientation of measurement into input-oriented DEA model and output-oriented DEA model. (Coelli et al., 2005: 161-162, 172)

Constant returns to scale (CRS) assumes that change in production outputs is directly proportionated to change in production inputs without regard to variation in size of operating firms. In other words, CRS assumes that variation in scale of

operations among firms does not affect their efficiency. In contrast, variable returns to scale (VRS) assumes that change in production outputs is not essentially related to change in production inputs. Therefore, when firm's scale of operation is larger, its efficiency can be either increased or decreased. When increase of output is more than proportionate increase of input, the condition of increasing returns to scale (IRS) exists. However, when increase of output is less than proportional increase of input, decreasing returns to scale (DRS) instead occur. (Nakhun Thoraneenitiyan, 2007: xvi)

Input-oriented analysis assumes input minimization behavior of firm. This means that firm is assumed to minimize its use of production inputs while maintaining production of at least the same amount of outputs. In contrast, output-oriented analysis instead assumes output maximization behavior. Given certain amount of inputs, firm is assumed to maximize its production outputs. (Coelli, 1996: 5-7)

Figure 3.4 illustrates the concept of technical efficiency measurement by DEA under CRS and VRS technology in both orientations of analysis. Consider a production process involving single input and single output, x-axis represents amount of input used by all analyzed firms and y-axis shows amount of their production output. DEA constructs a non-parametric technical efficiency frontier over observed firms and measures of all firms can be computed relative to the constructed frontier. There are two technical efficiency frontiers illustrated in this figure, CRS and VRS frontiers. As mentioned earlier, CRS assumes that variation in size of firm's operation does not affect its efficiency, then the CRS frontier is constructed only by the firm which exhibits characteristic of CRS or changes in output and input are directly proportionate. In contrast, VRS frontier constructed by DEA seems to envelop the data more tightly by piece-wise linear combinations involving more number of

efficient firms. In estimation of VRS frontier, additional constraint is added to the method of frontier construction to ascertain that inefficient firms with different scale of operation are only benchmarked against their efficient peers with relatively the same size of operation. The frontier estimation method is thus in accordance with the VRS assumption that variation in scale of operation would influence efficiency of considered firms. Without this restrictive constraint in estimating CRS frontier, efficiency of firm may consequently be measured relative to efficient peers with significantly larger or smaller scale of operation. (Coelli et al., 2005: 172)

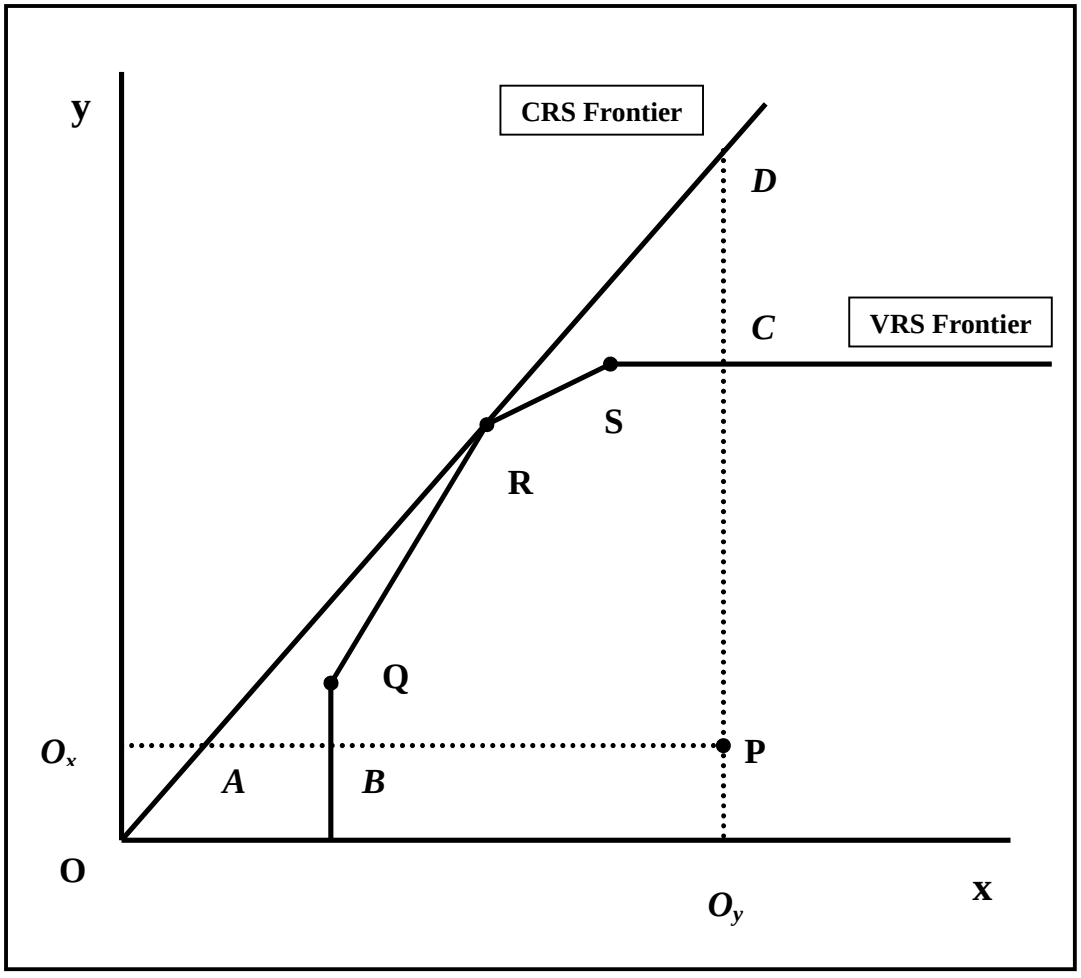


Figure 3.4: Technical efficiency measurement under CRS and VRS Technology

According to Figure 3.4, there are three technically efficient firms (Q, R, and S) operating on the VRS frontier while there is only one technically efficient firm (R) which exhibits characteristic of CRS and operates on the CRS frontier. CRS and VRS frontiers are regarded as referent frontier for measurement of TE when CRS and VRS assumptions are considered, respectively. Firm P is an inefficient firm which does not operate on any frontiers.

When cost minimization is the issue of interest, input-oriented measure of TE (TE_i) is considered. To improve technical efficiency of firm P in terms of minimal use of its input under CRS assumption, firm P must reduce its production input to the same level of point *A* on CRS frontier while maintaining the same level of output production. Therefore, input-oriented CRS measure of TE for firm P is indicated by the ratio of distance O_xA to that of O_xP ($TE_i^{CRS} = O_xA/O_x$P). Under VRS assumption, firm P is supposed to reduce its input to the level of point *B* on VRS frontier while level of its output remains the same. Thus, input-oriented VRS measure of TE for firm P is equal to the ratio of O_xB to O_xP ($TE_i^{VRS} = O_xB/O_x$P). Nevertheless, it is still questionable whether production at point *B* is truly efficient since firm Q can actually produce greater amount of output using the same input level as point *B*. This phenomenon is recognized as 'output slack' and it is equal to distance *B*Q in this case. Therefore, to be truly efficient, firm P must reduce its use of input to level of point *B* and produce more output to the same level of firm Q. (See Figure 3.4)

When output maximization is the issue of interest, output-oriented measure of TE (TE_o) is then considered. To enhance technical efficiency of firm P in terms of maximal production of its output under CRS assumption, firm P is supposed to increase its output to the level of point *D* on CRS frontier, using the same level of its

input use. Output-oriented CRS measure of TE for firm P is hence indicated by the ratio of distance O_yP to that of O_yD ($TE_o^{CRS} = O_yP/O_yD$). When VRS is instead assumed, firm P must maximize its output to the level of point *C* on VRS frontier, maintaining its level of input use. Output-oriented VRS measure of TE for firm P is thus equal to ratio of O_yP to O_yC ($TE_o^{VRS} = O_yP/O_yC$). However, it is also doubtful whether production at point *C* is truly efficient since firm S can produce the same level of output as point *C* while using smaller amount of input. This situation is recognized as 'input slack' and can be measured as distance of S*C*. Consequently, to be truly efficient, firm P is supposed to increase its output production to the level of point *C* and decrease its input use to the same level of firm S. It should also be noted that the phenomenon of 'slack' usually occurs when the piece-wise linear frontier estimated by DEA is parallel to any axes. Hence, it is generally recommended that technical efficiency measure together with non-zero slack should be described to provide precise measure of technical efficiency in any DEA analyses (Coelli et al., 2005: 164). (See Figure 3.4)

The DEA model used for frontier estimation in case of input orientation with CRS assumption was developed by Charnes, Cooper and Rhodes; and it was the first DEA model which was widely recognized in 1978 as mentioned earlier. This model is thus called input-oriented CRS CCR DEA model–CCR stands for Charnes, Cooper, and Rhodes to honor their development of the model. The CRS CCR DEA model for analysis of output orientation is also available. Later development of DEA model by Banker, Charnes and Cooper recognized in 1984 alternatively considered VRS assumption. The later developed model is thus called VRS BCC DEA model and

application of the model for analyses in both orientations are also feasible. (Coelli, 1996: 10)

(B) VRS BCC DEA Model

In this dissertation, VRS BCC DEA model applied for both orientations of analysis is of great interest due to its practical application in this healthcare context of analysis. As previously mentioned in Chapter II of this dissertation, there are some exceptional features of health system which cause market failure from economic viewpoint. These features of health system; such as restriction of competition, government subsidy, role of non-profit organization, and others; can potentially influence the firms to be not operating at their optimal scale of production. Consequently, the CRS assumption, which assumed that all considered firms are operating at their optimal scale, may not be fully appropriate since variation in scale of operation would affect efficiency of the firms. The CRS measure of TE would thus be confounded by scale efficiency (SE) or efficiency related to size of operation. The VRS measure of TE would be more appropriate since it indicates 'pure' technical efficiency which is destitute of effect from SE. (Coelli et al., 2005: 172)

Description of input-oriented VRS BCC DEA Model is commenced here with explanation of some related notation. (Coelli, 1996: 10)

N = number of all firms included in efficiency analysis

K = number of types of inputs used in production process

M = number of types of outputs produced in the production process

x_i = input vector used by an i-th firm

y_i = output vector of the i-th firm

$X = [x_1, x_2,\ldots, x_i]$ or K×N matrix of input vectors

$Y = [y_1, y_2,\ldots, y_i]$ or M×N matrix of output vectors

According to above notation, N firms are being considered in efficiency analysis. Each of these firms uses K inputs to produce M outputs. For an i-th firm, input and output vectors are symbolized by x_i and y_i, respectively. Data concerning inputs of all firms are represented by input matrix (X). Data regarding outputs of all firms are denoted by output matrix (Y).

As previously mentioned, DEA technique provides measure of technical efficiency by construction of non-parametric, piece-wise linear (best practice) frontier which encloses all data like an envelope. Consequently, all analyzed firms can be either lying on the constructed frontier (efficient firms) or lying beneath the frontier (inefficient firms). Operation of each firm is then examined by being compared to the constructed linear combination of the efficient firms which generally utilize fewer amounts of inputs while producing identical amount of outputs (input-oriented analysis). The DEA efficiency frontier is constructed through solving mathematical linear programming problems, N times or once for each of all firms. Measure of efficiency for each firm can also be obtained through the calculation. The envelopment form of the input-oriented VRS BCC DEA can be specified as followed.

$$\begin{aligned} &\min_{\theta,\boldsymbol{\lambda}} \theta, \\ &\text{subject to} \quad -y_i + Y\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad \theta x_i - X\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad N1'\boldsymbol{\lambda} = 1, \\ &\qquad\qquad \boldsymbol{\lambda} \geq 0, \end{aligned} \qquad \ldots (1)$$

where θ is a scalar and it represents input-oriented measure of technical efficiency (TE_i). The θ value can range as $0 \leq \theta \leq 1$. The θ value of 1 indicates that the firm is operating on the frontier and is regarded as technically efficient firm. Given λ_i to represent vector of peer weight, **λ** in the model denotes $[\lambda_1, \lambda_2, \ldots, \lambda_i]$ or N×1 vector of peer weights which defines linear combination of peers for the i-th firm. The constraint N1'**λ** = 1 is regarded as the convexity constraint for the VRS assumption. (Coelli, 1996: 18-19)

As earlier mentioned in description of Figure 3.4, a constraint is added to the original CRS frontier estimation method (CRS CCR DEA Model) to allow estimation of VRS frontier. The added constraint for construction of VRS frontier is actually this convexity constraint (N1'**λ** = 1) in the VRS BCC DEA Model discussed here. The convexity constraint ensures that each inefficient firm is only benchmarked against efficient peers with similar scale of operation. Since the convexity constraint is omitted in the CCR DEA Model, it becomes the only difference between the two DEA models. (Coelli, 1996: 18-19)

The following Figure 3.5 provides graphical presentation of how the mentioned DEA model works to identify θ value for the i-th firm. In this figure, there are 5 firms (A, B, C, D and E) included in technical efficiency measurement by input-oriented VRS BCC DEA Model. These firms utilize two production inputs to produce a single output. The DEA model constructs technical efficiency frontier as piece-wise linear boundary based on observed data points (e.g. all analyzed firms). The constructed frontier envelops the whole data there is not any observation positioned outside this boundary. In this figure, the constructed frontier is structured by linear combinations B'BCC'. Firm D is an example of inefficient firm being analyzed. The

DEA model takes the firm D for linear programming problem and proceeds to radially contract its input vector as much as possibly can within feasible input set. This radial contraction creates a projected point *D′* on linear combination BC of the frontier. Given that input vector of firm D is x_D, the input vector of the projected point *D′* is thus $x_{D'}$. The $x_{D'}$ can be calculated as followed.

$$x_{D'} = (\lambda_B * x_B) + (\lambda_C * x_C),$$

$$\text{so that } x_{D'} \leq x_D$$

Given that the input-oriented measure of technical efficiency (TE_i) is θ_D, the θ_D is:

$$\theta_D = TE_i = OD'/OD \ (\leq 1),$$

$$\text{so that } x_{D'} = \theta_D x_D$$

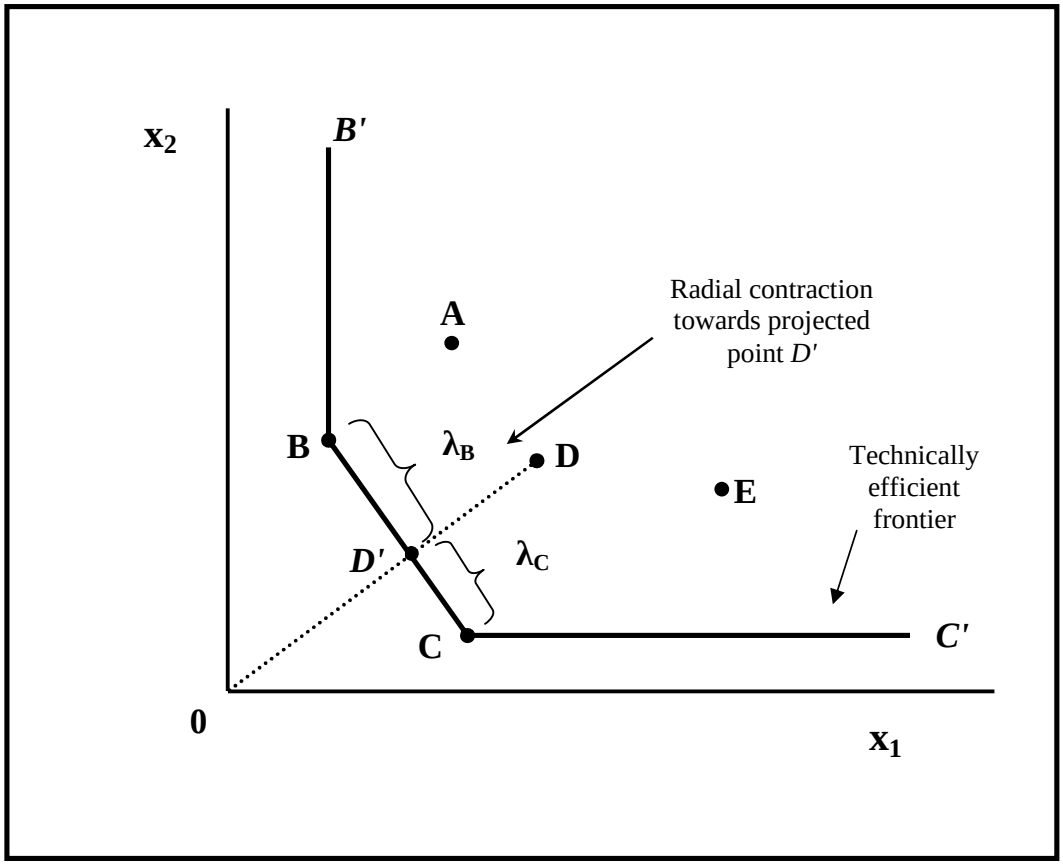


Figure 3.5: Efficiency measurement by input-oriented VRS BCC DEA Model

The model seeks to identify values of θ and **λ** which contribute to a minimal value of θ. In other words, the model proceeds to indicate technical inefficiency as a proportionate reduction of input consumption. If TE_i of firm D is 0.75, this means that firm D could decrease its use of all inputs by 25% without decrease of its output, and this refers to the production at projected point *D′*. Since the projected point *D′* is positioned on linear combination which joins point B and C, firm B and C are therefore regarded as 'peers' of firm D and these firms define technically efficient operation for firm D. Point *D′* is a linear combination of BC and peer weights for constructing *D′* are λ_B and λ_C, respectively.

According to the example of firm D in Figure 3.5, the VRS BCC DEA Model (1) can be rewritten as followed.

$$\min_{\theta,\lambda} \theta,$$

$$\text{st} \quad -y_D + (y_A\lambda_A + y_B\lambda_B + y_C\lambda_C + y_D\lambda_D + y_E\lambda_E) \geq 0,$$

$$\theta x_{1D} - (x_{1A}\lambda_A + x_{1B}\lambda_B + x_{1C}\lambda_C + x_{1D}\lambda_D + x_{1E}\lambda_E) \geq 0,$$

$$\theta x_{2D} - (x_{2A}\lambda_A + x_{2B}\lambda_B + x_{2C}\lambda_C + x_{2D}\lambda_D + x_{2E}\lambda_E) \geq 0,$$

$$N1'\boldsymbol{\lambda} = 1,$$

$$\boldsymbol{\lambda} \geq 0,$$

where $\boldsymbol{\lambda} = (\lambda_A, \lambda_B, \lambda_C, \lambda_D, \lambda_E)'$

Unlike the input orientation of the analysis which focuses on minimizing consumption of production input and amount of input use is a factor critically influences decision making, output orientation of analysis using the VRS BCC DEA Model is also feasible to serve the objective of output maximization given the constraint of fixed amount of input use. The output-oriented VRS BCC DEA Model is

very much alike its input-oriented model. The output-oriented model can be specified as followed. (Coelli, 1996: 23)

$$\begin{aligned} &\text{Min}_{\phi,\lambda}\ \phi, \\ &\text{subject to} \quad -\phi y_i + Y\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad\ \ x_i - X\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad\ \ N1'\boldsymbol{\lambda} = 1, \\ &\qquad\qquad\ \ \boldsymbol{\lambda} \geq 0, \end{aligned} \qquad \ldots (2)$$

where ϕ value ranges as $1 \leq \phi < \infty$. The $\phi - 1$ value indicates proportionate increase in quantity of outputs produced by the i-th firm when amount of input is kept unchanged. The value of $1/\phi$ is the output-oriented measure of technical efficiency (TE_o) ranging from 0 to 1. (Coelli, 1996: 23)

One feature which should be emphasized is that the input- and output-oriented DEA models will construct exactly the same technical efficiency frontier and indicate the same group of efficient firms operating on the frontier. Under CRS assumption, TE measures obtained from both orientations of analysis are equivalent. Only under VRS assumption that the difference in TE measures of the two orientations of analysis may exist when inefficient firms (only) are being evaluated. (Coelli, 1996: 24)

It should also be remarked that, since VRS DEA frontier envelops the observations in the tighter manner than the CRS DEA frontier as illustrated in Figure 3.4, VRS measure of TE is therefore either equal to or larger than that of CRS. The CRS measure of TE can also be regarded as ‘overall’ measure of TE which comprises ‘pure’ TE and SE as previously mentioned. The relationship of these measures can be summarized in equation form as followed.

$$SE_i = TE_i^{CRS} / TE_i^{VRS}$$

SE equal to 1 indicates scale efficiency or CRS situation. SE less than 1 would identify scale inefficiency.

3.3 Application of DEA in Dental Service: A Literature Review

(A) Application of DEA in Dental Service in International Literature

Among all analytical methods of efficiency measurement applied for efficiency analysis in health care, DEA is the most commonly used technique and its major application is to measure technical efficiency. Hollingsworth and colleagues first provided a review of DEA application in health care in 1999 and up to 91 studies published during from 1983 to 1997 were included. Nevertheless, most of the studies focused on measuring hospital efficiency and there was none of efficiency analyses devoted to measuring performance in dental service provision in this period of publication. (Hollingsworth et al., 1999: 163-164)

Hollingsworth further provided periodic review of DEA application in health care in 2003 and 2008. In his 2003 review, 188 published articles related to frontier techniques of efficiency analysis were included. DEA again took the dominant role in literature regarding efficiency analysis in health care. There were 2 studies devoted to efficiency analysis in dental service provision. (Hollingsworth, 2003: 213, 215-216) These studies were published in 2000 and 2002 (Buck, 2000: 247-280; Linna, Norblad, and Koivu, 2002: 343-353). In Hollingsworth's 2008 review, as many as 317 published articles related to frontier efficiency analysis were additionally reviewed. However, there were only 2 additional studies applying DEA to dental service mentioned in this review. (Hollingsworth, 2008: 1107-1128) One of the mentioned studies was undertaken by Parkin and Devlin and content of this study was mentioned

in a chapter of a book (Parkin and Devlin, 2003: 143-166). The other study was published as a journal article in 2003 (Coppola, Ozcan, and Bogacki, 2003: 445-456). In this dissertation (by the time of early 2013), there are 2 additional studies found related to this review. These studies were published in 1990 and 2004 (Gietzmann, 1990: 125-137; Widström, Linna, and Niskanen, 2004: 31-40). These studies are summarized in Table 3.3.

Gietzmann initially explored use of DEA in oral health care context. The aim of the study was to explore whether DEA could be a practical performance measurement approach in not-for-profit provision of community dental screening service. The service of interest was oral health screening with focus on detection of dental caries in school children. Inputs and outputs were adopted from recommendation by committee of district dental officers. Multiple inputs were population GDP, percentage of population in selected social classes, percentage of population with father not born in New Commonwealth or Pakistan, percentage of school children with complete treatment of dental caries in 1987, percentage of caries-free school children in 1987, and dental screening hour. Multiple outputs were number of children screened in the program, percentage of school children with complete treatment of dental caries in 1888, and percentage of caries-free school children in 1988. Data were obtained from district dental officers in 34 districts. The study primarily identified efficient and inefficient firms by relative efficiency score. The study also addressed difference in assessment results revealed by DEA and other alternative methods such as cash limits and basic performance indicators. (Gietzmann, 1990: 125-137)

Table 3.3: Summary of published articles related to application of DEA for efficiency measurement in dental service provision

Author	Objective	Data	Method
Gietzmann (1990)	To explore use of DEA in new context of not-for-profit community dental service with focus on dental caries screening program in England.	Multiple inputs and outputs obtained from district dental officers providing oral health screening in 34 districts.	DEA with comparison to other alternative method of performance measurement
Buck (2000)	To evaluate efficiency of Community Dental Service (CDS) in provision of public dental services including screening, treatment and prevention in the national context of England.	Multiple inputs but focus only on those related to labor (lack of capital input). Multiple outputs related to three main services (screening, treatment and prevention)	DEA with additional Probit and Tobit analyses
Linna, Norblad, and Koivu (2002)	To measure technical and cost efficiency in public dental service provision in the national context of Finland.	Multiple inputs and multiple outputs obtained from 228 health centers	DEA with additional Tobit analysis
Coppola, Ozcan, and Bogacki (2003)	To evaluate provider performance in provision of posterior dental restorations and to identify factors which may affect durability of the restoration	Multiple inputs and a single output. Total number of 279,999 restorations and 1,241 firms providing 100 or more encounters were included.	DEA and additional statistical analysis (Chi-square test)
Widström, Linna, and Niskanen (2004)	To identify technical and cost efficiency of Public Dental Service (PDS) in the national context of Finland.	Composite measures of input and output based on data obtained from PDS in 228 municipalities	DEA with additional Tobit analysis

Buck conducted an efficiency analysis using DEA method to evaluate performance of Community Dental Service (CDS) in provision of main community-based dental services in England. The dental services included oral health screening, dental treatment, and preventive dental intervention. There were 2 main input variables including total working hours of dental officers and total working hours of other allied oral health personals (oral hygienists and oral therapists). Therefore, input variables in this study focused only on those related to oral health professionals and there was none of capital inputs included, due to unsuccessful collection of financial information regarding the CDS. The study thus claimed that CDS was a labor intensive service and lack of capital inputs would not be a critical issue. The study also defined 3 service outputs including total number of patients being screened, numbers of oral hygiene instruction and preventive contacts, and numbers of episodes of dental treatment. Relative efficiency measures among CDS were revealed. Probit and Tobit analyses were additionally undertaken but could not identify any external factors related to efficiency in provision of the service. (Buck, 2000: 247-280)

Linna and colleagues conducted a study to measure both technical and cost efficiency of public dental service in the national context of Finland. Data were obtained from 228 health centers which provided primary dental services. Inputs variables included total number of dentists, total number of other related personals, total cost of material and instrument, and total operating cost of each health center. The output variable was categorized into patient-based output model and visit-based output model. In patient-based output model, patients were categorized into 3 age groups which defined 3 patient-based outputs. In visit-based output model, each category of the previously defined age groups was further classified by number of

visits either to dentists or to hygienists and assistants. This defined 6 visit-based outputs. The study also included several explanatory variables for additional Tobit analysis. Technical and cost efficiency measures were revealed in its results. The study also addressed that change in individual efficiency scores was sensitive to different options of output definition. Nevertheless, sets of factors related to inefficiency were similar regardless of the difference in the output variable definitions. (Linna, Norblad, and Koivu, 2002: 343-353)

Coppola and colleagues conducted a study to evaluate performance of dentists in provision of posterior dental restorations (composite and amalgam fillings). The task to identify factors which might influence longevity of the restorations was also undertaken. Multiple inputs for DEA model were experience of providers, severity levels of carious lesion restored by amalgam filling, and severity levels of carious lesion restored by composite filling. Single output was longevity of the posterior restoration. The study primarily revealed efficiency scores of analyzed providers and classified these providers to be either efficient or inefficient. Chi-square test was used to identify statistically significant difference in experience of efficient and inefficient providers. (Coppola, Ozcan, and Bogacki, 2003: 445-456)

Widström and colleagues conducted a research to determine technical and cost efficiency of Public Dental Service (PDS) in the national context of Finland. They also sought to identify factors related to efficiency scores by means of Tobit analysis. Data were obtained from 228 units of PDS throughout the nation. DEA input was a composite measure of related inputs of labors, materials, and costs. DEA output was number of dental service recipients. Considerable variation in cost efficiency among

analyzed PDS was revealed and several factors related to efficiency and inefficiency were identified. (Widström, Linna, and Niskanen, 2004: 31-40)

(B) Application of DEA in Health Care in the Context of Thailand

Although literature review in this section focuses mainly on application of DEA in dental service specifically in the context of Thailand, to the best of author's knowledge, there is currently none of DEA application for performance measurement in dental service delivery in the mentioned context. Therefore, this section of literature review is thus devoted to mention three major studies applying DEA for efficiency analysis in the health care context in Thailand.

Thamana Lekprichakul conducted his doctoral dissertation regarding hospital efficiency analysis in 89 Thailand's public provincial hospitals in 2001. The primary aim of the study was to assess whether behavior of Thai provincial hospitals were in consistence with cost minimization assumption. The study applied both parametric and non-parametric approaches in frontier efficiency measurement to determine sensitivity of results based on options of analytical techniques. Results showed that the behavior of the provincial hospitals did not conform to cost minimizing assumption since there was cost inefficiency which significantly increase the hospital cost from the minimum cost reference. Improvement of technical and allocative efficiency would substantially decrease such hospital cost. This study also addressed sources which resulted in cost inefficiency, technical change over period of time, and total factor productivity growth in the analyzed setting. (Thamana Lekprichakul, 2001: 135-341)

Direk Patmasiriwat conducted two studies concerning hospital efficiency analysis. In the first study published in 2007, there were 95 provincial and regional hospitals included for evaluation of cost efficiency. Two main inputs were personnel costs and operating costs. Three service outputs were days of hospital admission, extent of outpatient services, and number of referred patients that each hospital accepted for further care. The study revealed average cost efficiency of all evaluated hospitals and compared numbers of best practice units assessed under both assumptions on CRS and VRS. The study suggested further in-depth investigation by means of qualitative research to be undertaken in both cases of best practice and inefficient practice. In case of best practice, further investigation would enable understanding of strategy for efficient hospital operation. In contrast, for the other case of inefficient operation, qualitative investigation would provide understanding of limitations and features specific to the local context which might hinder good hospital operation. (Direk Patmasiriwat, 2007: 96-126)

In the second study of Direk Patmasiriwat, published in 2009, focus of the study has been changed to efficiency measurement in medium-sized district hospitals in Thailand. In this study, there were 166 district hospitals included in cost efficiency analysis using DEA. The same set of inputs and outputs as the previously-published study was adopted. This study indicated average cost efficiency measure and number of best practice units under VRS assumption. In-depth investigation by qualitative method was also recommended for both cases of efficient and inefficient hospital operation as the previous study. (Direk Patmasiriwat, 2009: 79-104)

CHAPTER IV

RESEARCH METHODOLOGY

This chapter is devoted to description of research methodology specifically employed in this dissertation. The research methodology comprises two main parts: quantitative analysis of technical efficiency measure and related factors, and qualitative study of efficient service management strategy in selected best practice firms. Explanation of quantitative methods is based broadly on the information and theoretical framework previously discussed in Chapter II and III, respectively. Therefore, these chapters should be referred to for detailed explanation of some terminologies and concepts. Description of the previously-mentioned terms and concepts would be only of concise extent in this chapter.

4.1 Quantitative Phase of Study

4.1.1 Dental Service of Analysis

Quantitative phase of this dissertation focuses on efficiency measurement in public provision of high-cost dental prosthetic service under UC in district hospitals throughout Thailand in fiscal year 2010 and 2011.

(A) Scope of the high-cost dental prosthetic service

Based on the list of high-cost health care instruments and interventions specified by the Bureau of Claim Administration, the high-cost dental prosthetic service in this context analysis is defined as provision of the following 4 categories of removable acrylic dentures (Bureau of Claim Administration, 2012: 242-243):

- Partial denture with 1-5 replaced teeth
- Partial denture with more than 5 replaced teeth
- Single denture
- Complete denture

For additional details regarding these categories of removable acrylic dentures, see also Table 2.4 in Chapter II of this dissertation.

(B) Eligible service users

Eligible service users can utilize the high-cost dental prosthetic service free of charge only once in every 5 years. To be eligible for the service, characteristic of dental patient must conform to the following criteria.

- Patient must be UC beneficiary officially registered at corresponding district hospital where the service is provided.
- Patient must be either partially or totally edentulous.
- The edentulism must be professionally assessed as in need of dental prosthetic replacement.

Exclusion: Those UC beneficiaries who received complete denture service through Dental Prosthetic Campaign for the Elderly were not included in this analysis due to offering of incentive for dental professionals who provided the service.

(C) Service funding system

The high-cost dental prosthetic service is unique in that it is the only routine dental service which has been included in the list of high-cost health care instruments and interventions under budgetary control by the Bureau of Claim Administration

(Bureau of Claim Administration, 2012: 242-243). Unlike other routine dental services which are financially supported through UC per capita funding, the dental prosthetic program is uniquely funded through fee-for-service reimbursement system. Dental unit of district hospital needs to initially provide the dental prosthetic service and inform financial unit of the hospital to prepay operating expenses prior to claim for service reimbursement. The hospital financial unit normally takes responsibility for the prepayment by budget allocation from UC per capital funding. The financial unit also further submits evidence of service provision and claim documents via internet-assisted E-Claim system to the Bureau of Claim Administration for service reimbursement. Ultimately, after validation of the claim documents, the Bureau of Claim Administration pays back the reimbursement to the district hospital. The service reimbursement is available for related operating expenses; such as material costs, costs related to denture fabrication in dental laboratory, and others. The service reimbursement does not include personnel cost of service production based on the fact that dentists providing the service have already been paid their salaries to deliver this routine dental service as well as other routine dental care interventions; such as dental extraction and dental restoration. For thorough details of claim administration, section 2.3 of Chapter II in this dissertation should be referred to.

(D) Service characteristics and considerations for efficiency improvement

The high-cost dental prosthetic service is appealing for efficiency analysis and efficiency improvement in service delivery due to several service characteristics and challenges in service management as followed.

a) Multi-stage nature of service production

Production of the dental prosthetic service is a multi-stage process in nature. To give clearer view on the multi-stage nature in production of this service, a case of complete denture fabrication is considered as an example. List of procedures in complete denture fabrication are illustrated in Table 4.1 (Nallaswamy, 2003: 10-11).

Table 4.1: Summary of clinical and laboratory procedures in complete denture fabrication

	Clinical procedures		Laboratory procedures
1.	Diagnosis and treatment planning • History taking • General examination • Oral examination • Radiographic examination • Evaluation of previous dentures and pre-treatment history • Diagnostic impression		
		2.	Fabrication of diagnostic cast
3.	Treatment planning		
4.	Pre-prosthetic oral preparation		
5.	Primary impression		
		6.	Fabrication of primary cast and individual tray
7.	Border molding and final impression		
		8.	Fabrication of master cast
		9.	Fabrication of temporary denture base and occlusion rims
10.	Jaw relation registration		
11.	Orientation relation using face-bow		
		12.	Face-bow transfer and articulation
		13.	Attachment of tracers to occlusion rims
14.	Gothic arch tracing		
		15.	Remounting mandibular cast
16.	Interocclusal records		
		17.	Programing articulator in accordance with the interocclusal records
		18.	Arrangement of anterior teeth
19.	Try-in anterior teeth		
		20.	Arrangement of posterior teeth in balanced occlusion
21.	Try-in verification		
		22.	Wax-up
		23.	Denture processing
		24.	Denture finishing
25.	Denture insertion, post-insertion check, and recall		

(Source: Nallaswamy, 2003: 10-11)

Since production of the high-cost dental prosthetic service involves multiple steps to be undertaken as earlier exemplified, consumption of health resource inputs (e.g. professional chair time, dental instruments, dental materials, and others) is consequently of much greater extent compared to other routine dental services. The multi-stage nature of the service production also significantly raises expenditure needed per care. Analysis and improvement of efficiency in service production would therefore be useful in reducing loss from inefficient or excessive resource use.

b) Challenges faced by service users

There are several challenging aspects regarding utilization of the high-cost dental prosthetic service faced by edentulous patients. Major challenges can be summarized as followed:

- Problem in access to the high-cost dental prosthetic service
- Dependence on service provider
- Requirement of pre-prosthetic oral preparation
- Requirement of multiple visits to hospital

Problem in access to public dental service in the context of Thailand has long been a major challenge faced by Thai dental patients and access to the high-cost dental prosthetic service is neither an exception. Evidence indicating such problem in utilization of the dental prosthetic service is the presence of long list of edentulous patients waiting for a considerable period of time to receive the service. The long waiting list of service users would primarily indicate disproportion between limited number of dentists supplying the service and much larger service burden.

Dependence on service provider is another challenging issue in utilization of the dental prosthetic service. Unlike other single-visit dental interventions which are

more likely to be provided and finished in one session, or dental emergencies that usually draw more of professional attention; patients requiring prosthetic service are often screened on the first visit and then added to the waiting list. Variation in length of period from the first screening visit to prosthetic treatment depends greatly on decision of dentists providing the dental care, whether to allocate their busy chair time to the time-consuming process of denture fabrication or to give priority to other single-visit or emergency dental treatments.

Requirement of pre-prosthetic oral preparation influences variation in length of pre-prosthetic period prior to commencement of dental prosthetic treatment. When the longer period of time is needed for the pre-prosthetic treatment, provision of the prosthetic service is consequently delayed. The pre-prosthetic oral preparation usually involves multiple dental procedures. For instance, partially edentulous patients often need periodontal treatment and dental restorations for their remaining teeth to cease progression of periodontal diseases and dental caries, respectively; and to ensure optimal condition for the placed dental prostheses to properly function. According to the mentioned fact, efficient management of pre-prosthetic service is also an enabling factor which further enhances efficiency in provision of the dental prosthetic service.

Since production of dental prosthetic service involves multiple procedures undertaken in dental office, patient is consequently required to make multiple visits to hospital. Although financial barrier to the dental prosthetic service can be overcome by funding from third party payer, rise in intangible costs by the requirement of multiple visits to hospital is still a problematic issue in service utilization from patient perspective. Examples of intangible costs in this context are costs related to transportation to hospital, loss of income regarding absence from work, and others.

These intangible costs could be minimized when optimal number of dental appointments is made and utility of each dental visit is maximized.

Consideration of these challenges in utilization of the high-cost dental prosthetic service faced by service uses would address areas of inefficiency in service delivery which need improvement to better benefit the patients. Efficiency analysis of the high-cost dental prosthetic service together with lesson learned from best practice dental unit would then be useful providing suggestions for efficiency improvement; especially on how waiting time can be shortened, how professional chair time can be allocated to allow better delivery of the prosthetic service, how pre-prosthetic service can be better managed, and how multiple dental appointments should be appropriately made with consideration of intangible costs and opportunity loss faced by the patients.

c) Challenges faced by local service providers

Provision of the high-cost dental prosthetic service also posts various challenges to local service providers. These challenges can be summarized as followed.

- Decision concerning whether to provide the high-cost dental prosthetic service
- Need of considerable chair time allocation for multiple clinical procedures required for denture fabrication
- Problems related to remote locations of local service providers
- Requirement of prepayment for operating expenses arise from provision of the high-cost dental prosthetic service
- Problems related to service reimbursement

Decision of dentist on whether to provide the high-cost dental prosthetic service can potentially influence availability of the service in corresponding district. This is due to the fact that district hospitals are the most significant dental service providers in the corresponding districts outside provincial main districts and the national capital. Private dental service providers and public-private partnership in dental service provision are limited in such areas. Therefore, decision not to provide the service or to provide limited extent of service can result in problem in access to care among local residents in need of dental prosthetic care. Dependence of the prosthetic service availability on such professional decision is also due to requirement of specialized skill of dentists in provision of the dental prosthetic treatment. Such specialized skill cannot be replaced by expertise of other allied dental personnel.

An important feature of the high-cost dental prosthetic service which makes it appealing for efficiency analysis is that dentists providing the service are allowed to make their own decision on whether to provide the high-cost service and to what extent the service would be delivered if it is intended to be provided. Unlike another dental prosthetic program, entitled Dental Prosthetic Campaign for the Elderly, which is implemented for a temporary period of time with monetary incentive given to dentists on case by case basis and specified quota setting on extent of service deliver; the high-cost dental prosthetic program is free of such reinforcement. Since the high-cost dental prosthetic program is rather a long-term program and the service is considered as a part of routine dental care generally provided by public hospitals throughout the nation; consequently, there is not any incentive given in addition to the salaries for dentists who provide the service. In other words, there is no monetary incentive given to positively reinforce the providers to deliver greater extent of the

prosthetic service. Negative reinforcement, such as compulsory regulation, or quota setting of certain service delivery extent are neither specified. Based on this characteristic of the dental prosthetic service, the service providers are thus enabled to make decision which results in variation of professional productivity of the service and this has provided an optimal condition for performance measurement by means of efficiency analysis.

As previously mentioned that provision of the dental prosthetic service usually involves multiple clinical procedures, dentists are consequently required to allocate their busy working hours to be engaged in these procedures. Once the decision to allocate considerable chair time to the dental prosthetic service is made, opportunity to provide other dental services by that dentist is thus forgone. Allocation of service time can thus be a critical issue in case of small dental unit with only a few dentists. Therefore, it is also interesting to study about how well small dental units have coped with such problematic issue.

Problems related to remote locations of service providers can potentially hinder efficiency in production of the service. For instance, hardship related to transportation in rural area can cause delay in denture fabrication process since the dental workpiece is needed to be transferred back and forth between hospital and dental lab for clinical and laboratory procedures, respectively. Some hospitals in rural areas may even need to send and receive their dental works by post on weekly basis due to inaccessibility of daily messenger service. In addition to the difficulty in transportation, extra transportation cost may be needed and this would contribute to increase in service production expenditure.

Since service reimbursement is adopted as funding method for the high-cost dental prosthetic service, hospital financial units are consequently required to allocate the UC per capita budget for prepayment of operating expenses related to provision of the service prior to claim for service reimbursement. This characteristic would add challenge in financial management especially among hospitals with more limited UC per capita budget due to smaller numbers of registered UC beneficiaries. In addition to this challenge, problems related to service reimbursement may also occur. These problems include delay of repay, risk of being not fully reimbursed, and need of claim appeal. Risk of these problems always exists in every claim made for service reimbursement and local providers need to bear this risk in every case of the high-cost dental prosthetic service provision.

d) Challenges faced by payer

Bureau of Claim Administration provides financial support for implementation of the high-cost dental prosthetic service nationwide. Implementation of the dental program nationwide involves considerable amount of public spending due to the high-cost nature of the service and considerable extent of service utilization. Consequently, the greatest challenge faced by the third-party payer would be the financial viability risk. Budget overrun would be an unfavorable consequent following excessive service provision. In addition, the misconduct of over claim for service reimbursement would adversely influence sustainability of the program. However, limiting the service extent would negatively impact on health and quality of life among edentulous patients. Efficiency analysis would be useful in identifying best practice units which efficiently use health resources–including the service funding–to

produce optimal amount of service outputs. Additionally, degree of inefficiency in the use of funding would also be indicated for further improvement.

(E) Firm behavior and analytical assumptions

Later in this dissertation, dental unit of each district hospital is considered and regarded as 'firm'. From production perspective, each firm takes a role of provider of the high-cost dental prosthetic service. Therefore, it uses service production inputs including labor, capital and materials to produce the service outputs comprising the four types of removable acrylic dentures. Efficiency analysis regarding production of the high-cost dental prosthetic service is based on the following assumptions of firm behavior.

- Each firm is the most significant provider of the high-cost dental prosthetic service in its corresponding district.
- All the firms are not assumed to be operating at optimal scale.

The first assumption ensures that the analyzed firms are the most important service providers of the public dental service in their corresponding areas. In other words, service production by each firm would represent extent of service delivery in the whole district. Share of service provision by local private dental providers through public-private partnership in provision in the high-cost dental prosthetic service, which might obscure the view on district hospitals' productivity of service, in each analyzed district does not occur. This assumption can be validated by non-existence of reimbursement for the high-cost dental prosthetic service to private providers in all analyzed districts. Therefore, study parameters concerning this service in all Thai district hospitals, including 'Crown Prince Hospitals', with verified numbers of

affiliated dentists are included in efficiency analysis. Central or provincial hospitals in main districts of all provinces, hospitals and community health centers in Bangkok– the national capital, and some general hospitals in more urbanized districts with service shared by private providers are excluded due to violation of this assumption.

Regarding the second assumption, variation in scale of operation is assumed to somehow affect efficiency of the service production. This means that when scale of operation of a certain firm is expanded larger, efficiency in the service production can be either enhanced or downgraded. Therefore, variable returns to scale (VRS) is assumed in this context of analysis. This assumption is based on the exceptional features of health system previously described in details in section 2.4 (B) of the Chapter II. Several factors; such as the role of not-for-profit organization, imperfect competition, and health insurance; may influence the firms not to be operating at their optimal scale. For example, since the analyzed firm is a not-for-profit organization and deficit from its operation is subsidized by public spending instead of strategies such as layoff, then the firm may still have too many personals. Then, increase in service output would be less than proportional excess in number of the personals. Assumption of VRS would be thus more appropriate than constant returns to scale (CRS) assumption in this context of analysis.

(F) Fiscal years of analysis

Efficiency analysis in this dissertation includes study parameters related to provision of the high-cost dental prosthetic service in two fiscal years of 2010 and 2011. Fiscal year 2010 is selected to highlight the situation when the claim system has changed to the new internet-assisted E-Claim system which has fully functioned to aid

claim process throughout the nation for the first year. Fiscal year 2011 represents the situation when the establishment of the National Dental Funds has been achieved and an attempt to specify budgetary value for the high-cost dental prosthetic service has been commenced.

Situation analysis in fiscal year 2010 provides useful information regarding real service delivery extent and related expenditure at the end of fiscal year which is actually not documented by the time of budget estimation for fiscal year 2011. Situation analysis in both fiscal years would also provide baseline information for budgeting of this specific service in later fiscal years and further evaluation of E-Claim system in developing service reimbursement process and service delivery extent.

Although the use of parameters from two fiscal years can be viewed as analysis of panel parameters, such approach of analysis would not be able to yield meaningful interpretation regarding technical change over time. This is due to the fact that the time period of only one year apart would be too short for production technology to change. Then, analysis of panel parameters would not be appropriate, regardless of the fact that methodological feasibility exists.

Therefore, efficiency analysis is undertaken separately for each of the fiscal years. This simply ensures the same time frame for service production among all firms compared in each fiscal year. Moreover, external phenomenon of extensive flooding experienced in many areas of Thailand during fiscal 2011, which adversely affected delivery of the dental service, would not cause misinterpretation of technical regress when that the firms situated in flooded areas exhibit regressive change in their operations compared to the fiscal year of 2010 when there was no flood. Separation of

efficiency analysis by each fiscal year assists in validation of the results and selection of best practice units which must exhibit technically efficient operations in both fiscal years.

4.1.2 Overview of Included Firms for Efficiency Analysis

Efficiency analysis in this dissertation focuses on the activity of the high-cost dental prosthetic service provision by dental units within district hospitals nationwide in Thailand in two fiscal years of 2010 and 2011. As earlier specified, each dental unit included in efficiency analysis is regarded as firm, representing a service production entity. Each firm makes its own decision concerning provision of the service and is capable of providing the service.

For both of the analyzed fiscal years, up to 724 dental units at district hospital level were allowed to provide the high-cost dental prosthetic service. However, there were 27 and 12 dental units without evidence indicating provision of the high-cost dental prosthetic service in all categories and claim for service reimbursement in fiscal year 2010 and 2011, respectively. Although these dental units are excluded from efficiency analysis, presence of these dental units without evidence of the service provision is still an important finding. This finding would call attention to authorized officers to further investigate for underlying reasons and provide appropriate support to these dental units in order to enable availability of the dental service to local residents in the corresponding districts. Other 34 and 3 dental units are further excluded from efficiency analysis in fiscal year 2010 and 2011, respectively. This exclusion is due to lack of validated number of affiliated dentists in each of these units. Nevertheless, outputs of service production and related operating expenses of

these excluded dental units are examined and found not to be critically large compare to the rest of the dental units included as analyzed firms in the efficiency analysis.

Consequently, up to 663 and 709 dental units of district hospitals nationwide in Thailand were included and regarded as firms in efficiency analysis of fiscal year 2010 and 2011, respectively. Inclusion of almost all of the dental units is to provide a macro view of the high-cost dental prosthetic program implementation at national level. In other words, generalizability of the efficiency measurement results to represent the national context is ensured by such inclusion. Moreover, such inclusion also prevents missing of best practice units, which are critical benchmarks in efficiency analysis, from any means of sampling.

4.1.3 Study Variables

Quantitative phase of this study is conducted to serve the two main research objectives: to measure relative technical efficiency among dental units of districts hospitals and to identify factors related to the measured technical efficiency. According to these two study objectives, study variables are consequently divided into two main groups: production-related variables and explanatory variables.

The production-related variables are analyzed to serve the first objective and they can be further classified into two groups: input variables and output variables. The input variables comprise number of affiliated dentists and total operating expenses related to provision of the high-cost dental prosthetic service in each analyzed firm. The output variables comprise the 4 categories of the high-cost removable acrylic dentures; including single denture, complete denture, partial denture with 1-5 replaced teeth, and partial denture with more than 5 replaced teeth.

The explanatory variables are analyzed to serve the second study objective. There are three included explanatory variables: hospital sizes indicated by different numbers of inpatient beds, location in different regions, and number of dentists (previously as the input variable). Relationship between these explanatory variables technical efficiency scores is assessed through Tobit analysis. Overview of the study variables in quantitative phase of study can be illustrated in the following Figure 4.1.

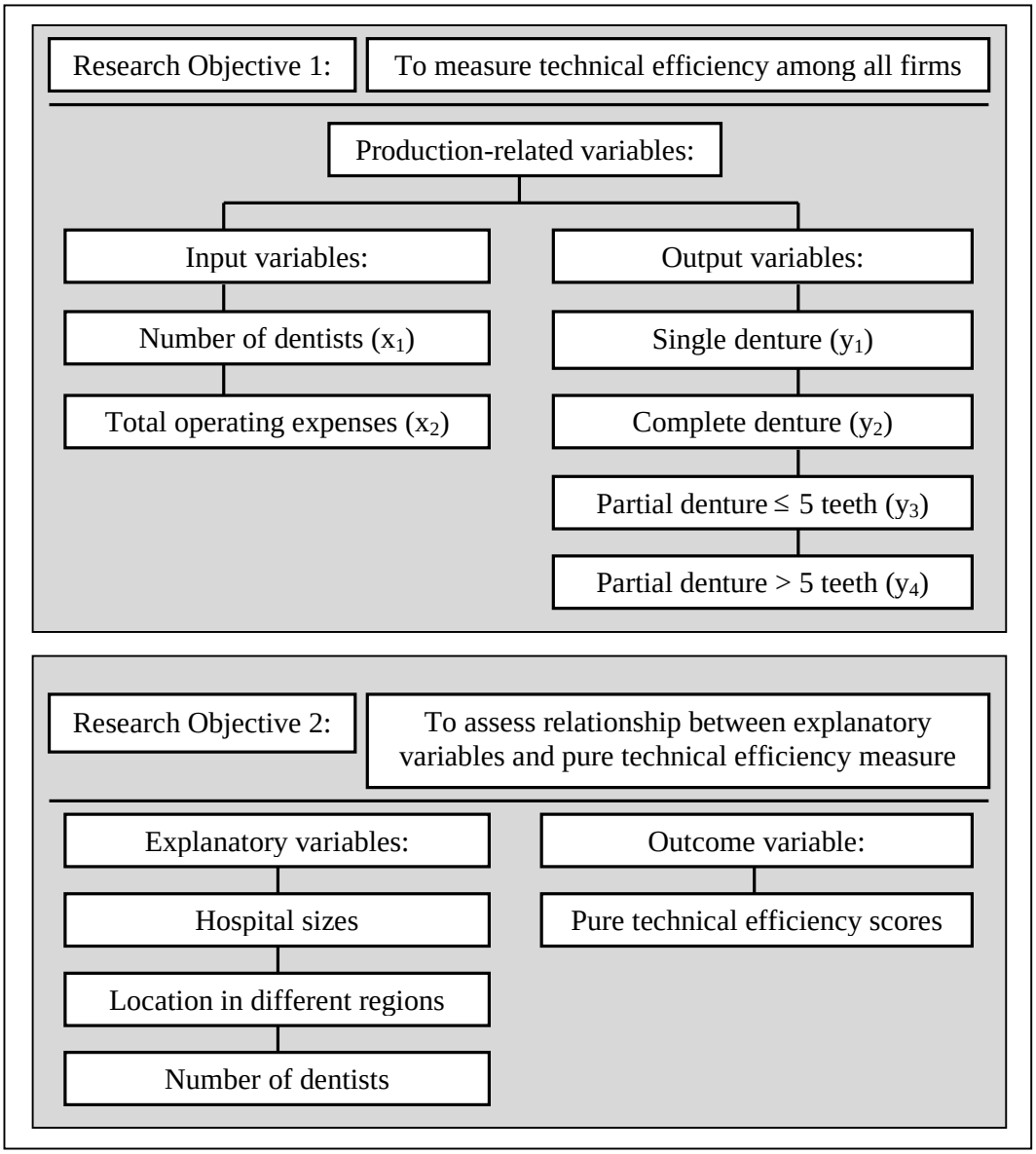


Figure 4.1: Overview of study variables in quantitative phase of study

(A) Input variables

Production of goods and services usually involves three major production factors including labor, capital and materials. For production of the high-cost dental prosthetic service, the mentioned production factors are represented by two main variables: number of dentists and operating expenses. These input variables can be defined as shown in Table 4.2.

Table 4.2: Definitions of input variables in efficiency analysis

Input variables:	**Units:**	**Definitions:**
(1) Number of dentists (x_1)	Person	Number of affiliated dentists in each dental unit
(2) Operating expenses (x_2)*	Thai Baht (THB)	Operating expenses accounts for capital, materials, transportation and dental laboratory expense.

* Values are adjusted by Inflation Adjustment Factor, IAF.

a) Number of Dentists

Number of dentists in each firm included in the efficiency analysis is obtained from annual survey of dentists working under authority of Department of Health, Ministry of Public Health (MOPH), in two fiscal years of 2010 and 2011. Bureau of Dental Health and Rural Health Division, Office of the Permanent Secretary for Public Health are responsible for conducting this annual survey under authority of the Department of Health. By authority of Director-General of the Department of Health, official correspondences are sent to Provincial Chief Medical Officers of all Provincial Public Health Offices nationwide to inform about the survey. Two additional documents are enclosed with each of the official correspondence. These

enclosures are instruction for submission of updated data of the dental professionals working in all public hospitals in each province and a copy of dental personnel data form for each of the public hospital with data of the dentists working in that hospital in previous fiscal year. Items of collected information can be illustrated in Figure 4.2.

Dental personnel data **Latest data in fiscal year: xxxx**
Area: _____ Province: _____
Hospital code: _____ Hospital name: _____
District Hospital size: *indicated by number of inpatient beds*
District: _____ Province: _____
Rural Health Division, Office of the Permanent Secretary for Public Health

Data items for each dentist:
Title:
Name-Surname:
Position:
Professional level:
Gender:
Date of Birth:
Commencement year of public employment:
Institution attended for bachelor degree:
Year of bachelor degree graduation:
Postgraduate training program:
Institution attended for postgraduate training:
Year of postgraduate training graduation:
Note:

** Please validate or update in all items of this form only and kindly return this form.
** In case of change of name/surname, please specify previous name/surname.
** In case of postgraduate training, please specify level or degree program, specialty, institution attended for postgraduate training, and year of postgraduate training graduation.
** In case of transfer, resignation, and retirement; please specify in details in Note.
** For new or transferred dentist, please complete all the data items and specify previous workplace (if applicable) in Note.

**Translated into English by author of this dissertation*

Figure 4.2: Dental personnel data form for annual survey of dentists

(Source: Office of the Permanent Secretary for Public Health, Rural Health Division; 2011)

Data collection period of the survey for fiscal year 2010 and 2011 was January to February in 2011 and 2012, respectively. The data collection period enabled conclusion of number of affiliated dentists in each district hospital anon after the end of each fiscal year and before allocation of newly-graduate dentists to the hospital in consecutive fiscal year. From this database, information specifically provided for this dissertation by the Bureau of Dental Health comprises district, province, name of district hospital, hospital size indicated by number of inpatient bed, number of affiliated dentists, commencement year of public employment for each dentist, and information of postgraduate training if applicable. Provision of multiple data items primarily assists in validation of the information. Dentists who were on study leave were excluded from the numbers of affiliated dentists. As mentioned earlier, district hospitals which did not submit the data in the survey were excluded from efficiency analysis in this dissertation. Consequently, there were 34 and 3 hospitals which were excluded from efficiency analysis in fiscal year 2010 and 2011, respectively. Comparability of the information in two fiscal years also assists in validation.

b) Operating expenses

Operating expenses become the other input variable in this efficiency analysis to represent the other two major service production inputs comprising capital and material. Moreover, the operating expenses also account for expenditure related service operation and transportation between dental clinical and dental laboratory during fabrication of dentures. From payer's perspective of analysis, value of the operating expenses related to provision of this service in each district hospital can be represented by total reimbursement value paid from the Bureau of Claim Administration back to the local provider. As earlier mentioned, since the major

challenge faced by payer is the financial viability risk, evaluation of efficiency in monetary resource actually paid to the local providers for production of the service would then be very important for budgetary control by payer. The use of reimbursement values would enable reflection of monetary resource use for the production of the service given constraint of limited budget availability as viewed from payer's perspective. In other words, the reimbursement value would be a proxy of operating expenses from payer's view.

Values of claim reported by each local provider to the Bureau of Claim Administration before accountancy audit of the claim documents were not used in this efficiency analysis. This is due to the fact that the claim values do not reflect real situation of budgetary control by the standard reimbursement price or ceiling price for each category of the dental prostheses, In other words, the instead use of reimbursement is to reflect the fact that no matter how high the claim value made from local provider is, for a certain kind of prosthesis, the local provider would be allowed to get paid only up to the highest reimbursement value which could not exceed the ceiling price specified by the payer. However, due to this measure of budgetary control, ones should be aware that the firm behavior in monetary resource use reflected by claim value would not be revealed by the scope of this study.

Conclusively, input variable of operating expenses in this efficiency analysis is represented by total reimbursement for the high-cost dental prosthetic service of each firm at the end of each fiscal year of analysis. Bureau of Claim Administration provides information regarding this input variable from the E-Claim database. Reimbursement specific to each of the four categories of dental prostheses is also obtained. Summation of all four category-specific claim values would assists in

validation of the total reimbursement value. Validation of these category-specific reimbursement values through calculation of 'per-case reimbursement' in each category and comparison of the reimbursement to the corresponding ceiling price is also enabled

Since the total reimbursement values used in this study were from fiscal year 2010 and 2011, the reimbursement values were thus past monetary values as compared to the time of this dissertation in 2012. Therefore, these total values were adjusted to become present values in 2012. Adjustment of monetary value in the past to become present value can be generally calculated using the following formula:

$$PV = Price \times IAF$$

$$= Price \times \frac{CPI_{present}}{CPI_{past}}$$

Given that, PV = present value

Price = price in the past year

IAF = inflation adjustment factor

$CPI_{present}$ = consumer price index of the present year

CPI_{past} = consumer price index of the past year

In this context of analysis, input variable of operating expenses can be represented by the present value which can be calculated as followed.

For fiscal year 2010: $PV = \text{Total reimbursement}_{2010} \times \frac{CPI_{2012}}{CPI_{2010}}$ … (1)

For fiscal year 2011: $PV = \text{Total reimbursement}_{2011} \times \frac{CPI_{2012}}{CPI_{2011}}$ … (2)

The CPI is a measure of average change over time in price of consumer goods and services purchased by households. Therefore, CPI is used for adjustment of past

monetary value to obtain the present value. To take into account difference in values of CPI among different provinces in Thailand, province-specific CPI is used in this analysis instead of the national CPI. Each of the CPI values used in equation (1) and (2) is an average value of all monthly-reported, province-specific CPI values in that corresponding calendar year. For example, to obtain value of 'CPI_{2010}' used in equation (1) for a certain province, all 12 values of monthly-reported CPI (from January to December) of that province are summed up first and then divided by 12 (number of months in the calendar year of 2010). Values of the monthly-reported, province-specific CPI for the year 2010, 2011 and 2012 are obtained from database of Bureau of Trade and Economic Indices, Office of the Permanent Secretary Ministry of Commerce. Reference base period, or the year that CPI is equal to 100, is 2007.

(B) Output variables

Output variables in this efficiency analysis can be defined as shown in the following Table 4.3.

Table 4.3: Definitions of output variables in efficiency analysis

Output variables:	**Units:** (Depend on types of dental prostheses)	**Definitions:** (Depend on types of dental prostheses)
(1) Single denture (y1)	Piece	Number of piece per one production of this prosthesis
(2) Complete denture (y2)	Set (1 set = 2 pieces)	Number of set (or two pieces) per one production of these prostheses
(3) Acrylic partial denture with ≤ 5 replaced teeth (y_3)	Piece	Number of piece per one production of this prosthesis
(4) Acrylic partial denture with > 5 replaced teeth (y_4)	Piece	Number of piece per one production of this prosthesis

Information regarding these output variables is obtained from the Bureau of Claim Administration at the end of fiscal year 2010 and 2011. Since parameters of these categories of service outputs are provided together with their category-specific reimbursement values, consistency between these parameters can then be assessed. Validation through the mentioned 'per-case reimbursement' approach with comparison to corresponding ceiling price is also enabled.

(C) Explanatory variables in Tobit regression analysis

To assess relationship between explanatory factors and the outcome of pure technical efficiency scores identified in efficiency analysis to represent efficiency in provision of the high-cost dental prosthetic service, Tobit regression analysis is undertaken in addition to the efficiency analysis by DEA. Three factors of interest, regarded here as explanatory variables, include hospital sizes, number of dentists, and locations in central region compared to those in all other regions combined. These explanatory variables can be defined as shown in the following Table 4.4.

Table 4.4: Definitions of explanatory variables in Tobit regression analysis

Explanatory variables:	**Units:**	**Definitions:**
(1) Hospital sizes (SIZE)	Inpatient bed numbers (10, 30, 60, 90, 120 or more)	Size of district hospital reflecting inpatient medical facility
(2) Number of affiliated dentists	Person	Number of affiliated dentists in each firm of analysis
(3) Location of firm	- Thai geographical regions: Central, North, North-east, East, South, and West - In this analysis, firms in central regions are compared to firms in all others combined.	

a) Hospital size

Information regarding hospital size in this dissertation is obtained from the Bureau of Dental Health together with the information related to number of dentists in each firm of analysis. As previously shown in Figure 4.2, hospital size indicated by number of inpatient beds in each district hospital is one of the data items included in the dental personnel data form for annual survey of dentists. The size of each hospital survey was actually provided in the mentioned survey form and officer of that local hospital could assist in validation of the information prior to return of the survey form. Collection of this parameter in two fiscal years also allows consistency checking. Information regarding the hospital sizes of all district hospitals nationwide published in Public Health Calendar by The National Health Association of Thailand is also used for consistency validation of this parameter.

b) Number of affiliated dentists (as earlier explained in input variable section)

c) Locations of firms in different regions

Thai geographical regions in this study are divided into six regions; comprising North, Central, North-east, East, West and South. The division into six regions is based on report of the National Geography Committee on geographical regions in Thailand, Office of the National Research Council of Thailand (Office of the National Research Council of Thailand, 1977: Online). List of provinces in each region can be summarized in the following Table 4.5.

Table 4.5: Geographical regions and corresponding provinces in Thailand

Regions:	**Provinces*:**
North	Chiang Rai, Phayao, Lampang, Lamphun, Chiang Mai, Mae Hong Son, Phrae, Nan, and Uttaradit (9 provinces)
Central	Ang Thong, Ayutthaya, Bangkok**, Chainat, Lopburi, Nakhon Nayok, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, Samut Sakhon, Samut Songkhram, Saraburi, Sing Buri, Phitsanulok, Uthai Thani, Sukhothai, Kamphaeng Phet, Nakhon Sawan, Phetchabun, Phijit and Suphanburi (22 provinces)
North-east	Amnat Charoen, Buri Ram, Chaiyaphum, Kalasin, Khon Kaen, Loei, Maha Sarakham, Mukdahan, Nakhon Phanom, Nakhon Ratchasima, Nongbua Lamphu, Nong Khai, Roi Et, Sakon Nakhon, Si Sa Ket, Surin, Ubon Ratchathani, Udon Thani, Yasothon, and Bueng Kan*** (20 provinces)
East	Chachoengsao, Chanthaburi, Chonburi, Prachinburi, Rayong, Sa Kaeo, and Trat (7 provinces)
South	Chumphon, Krabi, Nakhon Si Thammarat, Narathiwat, Pattani, Phang Nga, Phattalung, Phuket, Ranong, Satun, Songkhla, Surat Thani, Trang, and Yala (14 provinces)
West	Kanchanaburi, Ratchaburi, Phetchaburi, Prachuap Khiri Khan, and Tak (5 provinces)

*Revised list in 2007, **Bangkok is not included in this study due to no district hospital established in its area and dominance of private providers***Bueng Kan has just been established in 2011.

(Source: Office of the National Research Council of Thailand, 1977: Online)

Considerations for the division into six geographical regions can be summarized as followed.

Major criterion:

- Geographical locations

Minor criteria:

- Climate
- Racial culture

- Language and dialect
- Local pace of life

(Office of the National Research Council of Thailand, 1977: Online)

Degrees of rurality

For explanation in later chapters related to degrees of hardship in different districts, assignment of 3 degrees of rurality–comprising urban-like, rural, and very rural areas–to district hospitals in this study is based on the official correspondence of MOPH regarding list of district hospitals in hardship areas with dearth of health professionals in fiscal years 2009-2010 (Ministry of Public Health, 2009: official correspondence). MOPH has listed the district hospitals in hardship areas according to the following considerations:

- Difficulty in transportation
- Public utility shortage
- Local danger and risk
- Dearth of health professionals

(Kwanpracha Chiangchaisakulthai et al., 2011: 356)

4.1.4 Analytical approaches

(A) Perspective in Efficiency Analysis

Efficiency can be differently defined from various perspectives. For the service production activity of interest in this dissertation which is the delivery of high-cost dental prosthetic service by district hospitals nationwide, variation in definitions

of efficiency to be measured exist depending on whose point of view is taken into account.

For example, from patient perspective, being efficient in provision of this dental service would be defined by several characteristics such as:

- Input side:
    - Short duration in course of the dental care from the first oral screening visit to the last visit of denture delivery and related check-up (time spending)
    - The least possible number of dental visits that the patient has to make from home to hospital with consideration of related cost of transportation, work absence, and other related difficulties (visits and costs related to transportation)
- Output side:
    - Quality of the received dental care
    - Improvement in oral health related-quality of life

Above all, when efficiency in provision of the dental service is viewed from perspectives of policy makers and payer which is the focus of this dissertation, being efficient would be differently defined from the previously mentioned perspectives. Since funding of the high-cost dental prosthetic program through UC is aimed to reduce financial barrier and ease better access to care, policy makers would then be interested in how well the dental service can be delivered to the target beneficiaries by local providers. Payer would also concern about how much of the national global budget is needed to be allocated to pay of this program which would cause

opportunity loss of funding other important healthcare interventions. Consequently, efficiency from perspectives of policy maker and payer in this dissertation would be importantly defined by performance of dentists in delivery of the service to local beneficiaries and firms' behavior in consumption of monetary resource as appeared to payer's view. The payer's perspective is the most common perspective in health economic analysis–as well as societal perspective, and value of reimbursement is generally used to reflect costs in its cost identification method (Kirch, 2008: 1090). Even with setting of the ceiling price or the highest possible reimbursement value for each category of dentures for budgetary control by the Bureau of Claim Administration, reimbursement value is used in this study to reflect the firms' behavior in consumption of monetary resource with limited budget constraint in the real circumstance.

(B) DEA Technical Efficiency Measurement

Fundamental concepts and analytical method of DEA technical efficiency measurement have been thoroughly explained in details in sections 3.1 (D) and 3.2 of the previous Chapter III. Explanation of the analytical technique here is also based broadly on the theoretical framework in the mentioned sections. Therefore, explanation here would be concise and specific to the context of analysis in this dissertation. This thesis focuses on measurement of technical efficiency of firms in provision of the high-cost dental prosthetic service in fiscal year 2010 and 2011. Technical efficiency measurement is conducted separately for each fiscal year. The efficiency measurement is based on the VRS assumption, using VRS BCC DEA Model (Coelli et al., 2005: 172). Therefore, VRS technical efficiency score (TE_{vrs}),

also recognized as pure technical efficiency (PTE), for each firm can be identified as a major analysis result of technical efficiency measure. Input-oriented model assuming input minimization is used to take into account of the fact that, for a certain limit of health care budget and number of dentists, attempt to focus on delivery of quality dental service with minimal use of these input resources should be made. Consequently, excessive use of these resource inputs for service production can be exhibited as input slack and inefficiency in the analysis results.

For this context of analysis, there are 2 inputs (K = 2) comprising number of dentists in each firm and value of operating expenses adjusted by IAF, and 4 outputs (M = 4) comprising 4 categories of dental prostheses are specified for each of 663 (N_{2010}) and 709 (N_{2011}) firms under analysis in fiscal year 2010 and 2011, respectively. Input and output vectors can be denoted by x_i and y_i, respectively, for the i-th firm. X represents K x N input matrix and Y represents M x N output matrix. The input-oriented VRS technical efficiency score (TE_i^{VRS}) for each analyzed firm can be identified by solving linear programming problem in the input-oriented VRS DEA Model specified as followed.

$$\begin{aligned} &\min_{\theta,\boldsymbol{\lambda}} \theta, \\ &\text{subject to} \quad -y_i + Y\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad \theta x_i - X\boldsymbol{\lambda} \geq 0, \\ &\qquad\qquad N1'\boldsymbol{\lambda} = 1, \\ &\qquad\qquad \boldsymbol{\lambda} \geq 0, \end{aligned} \qquad \ldots (1)$$

where θ is the input-oriented VRS technical efficiency score (TE_i^{VRS}) which can range as $0 \leq \theta \leq 1$. The θ value of 1 indicates that the firm is technically efficient or operating on the technically efficient frontier. Such a firm is thus regarded as

technically efficient firm. Given λ_i to represent vector $\boldsymbol{\lambda}$ or N×1 vector of peer weights which defines linear combination of peers for the i-th firm. Therefore, the linear programming problem must be solved N times to provide θ for each of the N firms. The constraint $N1'\boldsymbol{\lambda} = 1$ is regarded as the convexity constraint for the VRS assumption.

As previously illustrated in Figure 3.4 in Chapter III of this thesis that VRS DEA technical efficiency frontier envelops the observations tighter than the CRS DEA technical efficiency frontier, TE_i^{VRS} is thus greater or equal to TE_i^{CRS} (Overall TE score). Then measure of input-oriented scale efficiency (SE_i) can be identified through the following relationship.

$$SE_i = TE_i^{CRS} / TE_i^{VRS}$$

SE equal to 1 would indicate scale efficiency or CRS situation. SE less than 1 would identify scale inefficiency. These measures of SE_i and TE_i^{CRS} are also also estimated by the DEA model. Additionally, output-oriented analysis is also undertaken to provide alternative view when outputs are aimed to be maximized given that inputs remain constant.

Efficiency scores in this analysis are estimated by the use of DEAP software, version 2.1 (Coelli, 1996)

(C) Investigating Factors Related to Service Provision Efficiency

To examine relationship between explanatory factors and the outcome of firms' efficiency scores, regression analysis is employed as analytical approach. Nevertheless, due to the fact that efficiency scores are limited to values ranging from 0 and 1, this dependent variable is consequently inappropriate for the ordinary least

square regression method which theoretically assumes normal distribution in its dependent variable. Therefore, Tobit estimation method is instead employed to explore the relationship of the explanatory variables and the outcome of efficiency scores. Values of TE_i^{VRS} are regressed on the three external variables including hospital sizes, geographical regions, and degrees of rurality. These three explanatory variables are variables as previously defined. Tobit regression model in this context of analysis can be written as followed.

$$TE_i^{VRS*} = \sum_j \beta_j \cdot x_j + v$$

$$TE_i^{VRS} = \begin{cases} TE_i^{VRS*} & \text{if } TE_i^{VRS*} > 0 \\ 0 & \text{if } TE_i^{VRS*} \leq 0 \end{cases}$$

$$v \sim N(0, \sigma^2)$$

This Tobit model supposes that the outcome of input-oriented technical efficiency measure under VRS assumption (TE_i^{VRS}) is linearly dependent on the explanatory variables x_j, via β_j which are parameters determining relationship between the explanatory variables and the dependent variable. The above model is also regarded as Type I Tobit model (Amemiya, 1985).

Tobit regression analysis in this dissertation is performed by the use of STATA statistical software, version 10.

(D) Statistical Analysis

Study parameters are statistically analyzed by SPSS software, version 17. Descriptive statistics are used for quantitative summary of the study parameters where appropriate.

4.2 Qualitative Phase of Study

In addition to quantitative phase of study, qualitative research method by means of in-depth interview is also undertaken to describe characteristics and management strategies of best practice dental units identified by the previous quantitative approach.

(A) Setting

Selection of 1-3 best practice dental units of district hospitals for qualitative phase of study would be based on pure technical efficiency scores revealed by the BCC DEA Model in the quantitative phase of study. Since all district hospitals nationwide are included in the quantitative analysis and no sampling is undertaken, the selected best practice dental unit would then be able to represent the best managerial method for successful implementation of the dental prosthetic program. Strategies and managerial lesson would be revealed from director and a representative dentist of the selected hospital. This would lead to policy suggestion from case of best practice dental unit.

(B) Key Informants

Informants for this phase of qualitative study include director and a representative dentist from dental unit of each selected district hospital. Informants also include dental prosthetic service recipients for the selected district hospital who received the service in fiscal year 2010-2011.

a) Director and representative dentist

For each selected district hospital, the director and one representative dentist are invited for in-depth interview. Inclusion criteria of these informants are as followed.

a) Selected hospital must be district hospitals of small, medium, or large size with high-cost dental prosthetic service provision under UC in fiscal year 2010-2011.

b) Selected hospital must be identified as technically efficient firm in provision of high-cost dental prosthetic service under UC by obtaining TE_i^{VRS} value of 1 in both fiscal years of 2010-2011 using the BCC DEA Model.

c) Selected hospital must provide at least one case of complete denture through the high-cost dental prosthetic program in fiscal year 2010-2011.

d) Selected hospital must have at least one case of complete denture service recipient who is willing to participate in the in-depth interview and can participate until the interview process is completed.

After inclusion of eligible hospital for the interview, researcher then further invites hospital representatives for in-depth interview. Inclusion criteria for selection of these representatives are as followed.

a) These representatives are hospital director (or personnel authorized by the director) and representative dentist of dental unit.

b) The representatives must be willing to participate in the in-depth interview and sign the consent forms.

c) The representatives can participate in the in-depth interview until the interview process is completed.

b) Dental prosthetic service recipients

About 4 dental prosthetic service recipients are invited for in-depth interview for each selected district hospital. Inclusion criteria for these service recipients are as followed.

a) At least one case of complete denture service recipient of the previously selected district hospitals in fiscal year 2010-2011 is interviewed. The other cases can be service recipients of any categories of the high-cost dentures.

b) Must be dental prosthetic service recipients who are willing to participate in the in-depth interview regarding satisfaction of the service until the interview process is completed.

(C) Procedures

Based on the results of DEA, best practice dental unit for each size of district hospital is identified. Qualitative study is conducted in order to describe in-depth characteristics and management strategies as role model of good practice which will be useful for other hospitals with some degree of inefficiency to learn and adapt the lesson from these units to develop their efficiency in service provision. Qualitative study by means of in-depth interview is planned to be conducted by interviewing three main stakeholders regarding the high-cost dental prosthetic service. These

stakeholders are directors of the identified best practice hospitals, representative dentist of each dental unit, and service recipients who have completely received the service. Face-to-face interview is used for interviewing the directors and representative dentists while telephone interview is used for interviewing service recipients. Scope of interview for directors and dentists would be about current quantity of service, self-assessed quality of service, and their perspectives regarding future development of service. Scope of interview for service recipients will be only limited to aspect of satisfaction of the received dental prosthetic service.

Prior to face-to-face interview at the selected district hospitals, these hospitals would be initially contacted through telephone to primarily check whether hospital directors and representative dentists are willing to participate in the interview. On the day of hospital visit, information regarding this study as documented in the information sheet for service provider would be thoroughly given to these participants. The participants can ask for additional information and explanation in any aspect that they do not understand from the interviewer.

For investigation of service recipient satisfaction regarding the dental prosthetic service, At least one of the service recipients with total tooth loss who have received the complete denture service would be selected since this condition would represent the extreme case of edentulism, and satisfaction and dissatisfaction regarding denture placement would then be most apparently represented. The other interviewed service recipients can be recipients of any other types of dental prostheses. For obtaining list of the service recipients (their names, details of received prosthetic care and telephone numbers) for in-depth interview, letter requesting

permission to obtain mentioned information from dental charts would be issued to hospital directors from College of Public Health Sciences, Chulalongkorn University.

Face-to-face interview process for each participant (director and dentist) would be undertaken only once and not exceed 1 hour in duration. Appointment for interview (date, time, and place) would depend principally on the participants. Telephone interview would be undertaken once for each service recipient and the duration of interview would not exceed half an hour including time for information about the research, verbal request of consent, and interview in details. Interview would be conducted by researcher himself without assistant. All interview sessions would be recorded on tape for further analysis and would be kept for only until completion of this study and the tape would then be destroyed.

(D) Data Analysis

Content analysis is adopted as analytical approach in this qualitative phase of study. Analysis of qualitative data is undertaken by researcher himself under supervision of his doctoral dissertation advisors and a lecturer with expertise in qualitative data analysis.

4.3 Ethical Consideration

To assure confidentiality of service recipients, directors and dental professionals, and district hospitals; none of the collected study parameters and analyses performed in this investigation can lead to identification of individual service recipients and dental providers. Parameters regarding service recipients and dental professionals in quantitative phase of study are also blinded to researcher and only

authorized person of the Bureau of Claim Administration collected these parameters for this study. Only the names of district hospitals are revealed to researcher. However, reveal of study results with identification of local dental units can be made only to those authorized as policy makers and allowed personnel of NHSO.

For obtaining consent of dental prosthetic service recipients for participation in the in-depth interview via telephone, information regarding the research project as shown in information sheet would be thoroughly given prior to verbal request of consent.

As mentioned earlier, local dental units analyzed to be inefficient in economic efficiency analysis will not be further investigated for underlying reasons. Only authorities in Bureau of Claim Administration, NHSO will have to decide on such issue for appropriate support of these dental units with no attention of blaming and punishment.

CHAPTER V

ANALYSIS OF RESULTS

Findings of this dissertation are presented in this chapter which can be divided into three major parts. The first part provides general description of the firms' characteristics and the production-related variables by means of descriptive statistics. The second part focuses on findings concerning technical efficiency measurement in provision of the high-cost dental prosthetic service by DEA model. The section also provides findings related to investigation of relationship between explanatory variables and the outcome of efficiency scores by means of Tobit regression analysis. The final part summarizes major findings from in-depth interview undertaken in the best practice units with efficient provision of the high-cost dental prosthetic service.

In order to show how research questions, research objectives, proposed key methodology and results are linked together, the following schematic diagram in Figure 5.1 illustrated that relationship. There are three main research questions and corresponding research objectives. The initial phase of study is the measurement of relative technical efficiency in production of the dental prosthetic service among all analyzed firms by DEA. Consequently, after firms' technical efficiency scores are obtained, these scores are used as dependent variable in Tobit regression analysis to identify related explanatory variables. Technical efficiency scores in both fiscal years together with other related service output characteristics are taken into consideration to select the best practice dental units for further in-depth interview. Ultimately, contents of interview are analyzed to provide managerial lessons learned.

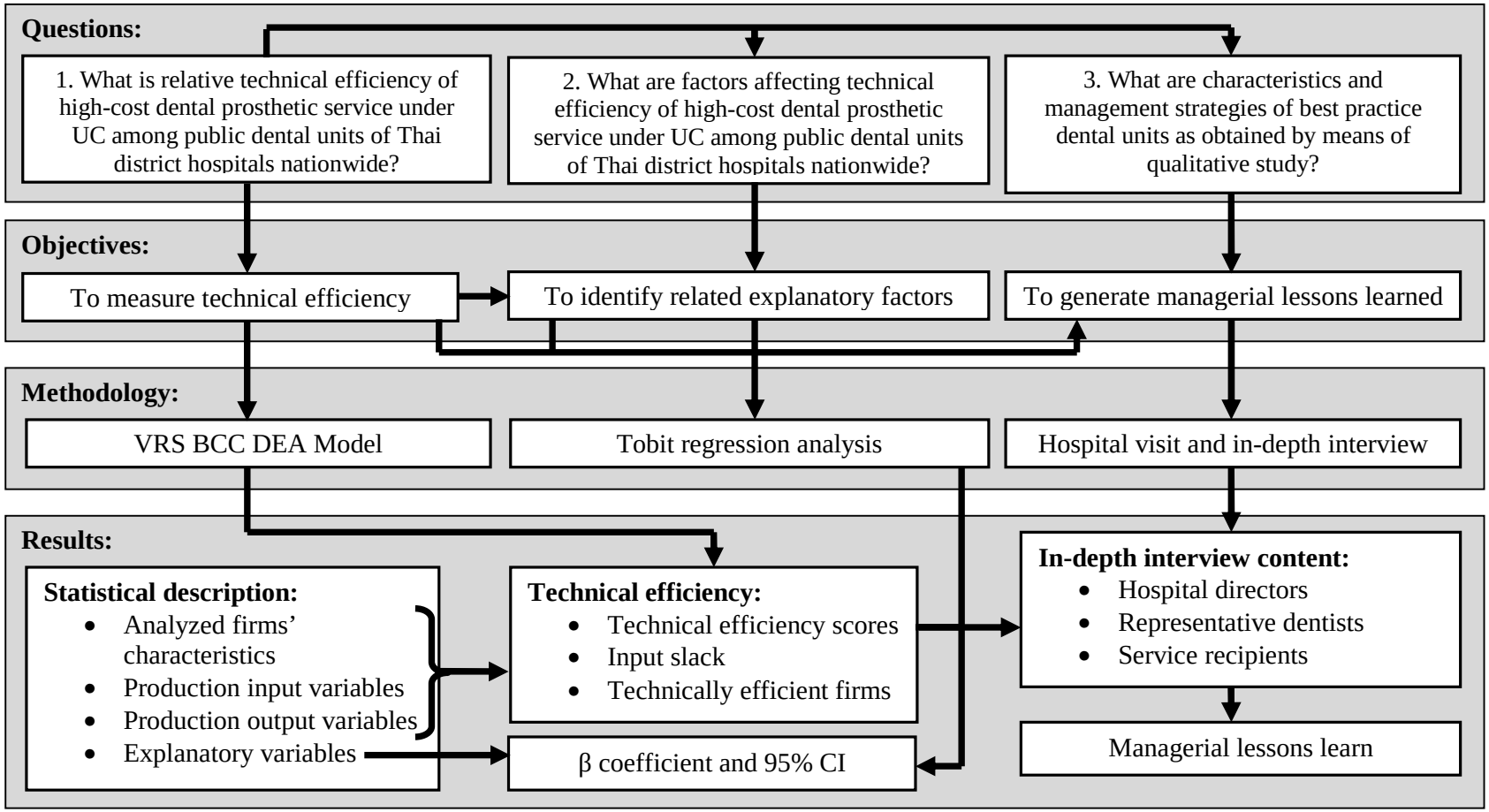


Figure 5.1: Relationship among research questions, objectives, proposed methodology and results

5.1 Descriptive Statistics of Observed District Hospitals and Study Variables

5.1.1 Characteristics of District Hospitals without Program Implementation

For both of the analyzed fiscal years, there were actually 724 district hospitals where implementation of the high-cost dental prosthetic service was observed by the Bureau of Claim Administration. Unfortunately, there were some of these hospitals which lacked evidence of service provision and claim for service reimbursement. Characteristics of these hospitals without provision of the service through this program for both fiscal years are summarized in the following Table 5.1.

In fiscal year 2010, there were 27 hospitals without the service and up to 17 of these were in the southern region. These hospitals were mostly of small sizes (10-30 inpatient beds). However, a large hospital was also found providing no service through the program. Most of these hospitals were found to have limited numbers of dentists, mostly with 1 to 2 dentists. When these hospitals were categorized by three degrees of rurality (MOPH, 2009: official correspondence), most of the hospitals without service were situated in the urban-like areas. Nonetheless, up to 9 from the total of 62 hospitals situated in very rural areas represented the highest proportion.

In fiscal year 2011, number of hospitals without implementation of the program has markedly decreased from the previous fiscal year. Number of these hospitals in the southern region has apparently declined to 4. Several features remained the same as previous. Small hospitals and limited numbers of dentists were still major characteristics of these hospitals. Nonetheless, number of hospitals without the implementation in very rural areas has notably decreased from the previous year. Those without the service situated in urban-like areas then clearly dominated other categories.

Table 5.1: District hospitals with no service provision through the high-cost dental prosthetic program in fiscal year 2010 and 2011

Features	Fiscal year 2010 (N = 27)							Fiscal year 2011 (N = 12)						
	Central (3)	North (1)	Northeast (5)	East (0)	South (17)	West (1)	Total (27)	Central (2)	North (0)	Northeast (3)	East (1)	South (4)	West (2)	Total (12)
Hospital sizes (Inpatient beds)														
Small (10-30)	1	1	4	-	15	1	22	-	-	2	1	4	1	8
Medium (60)	2	-	-	-	2	-	4	2	-	1	-	-	1	4
Large (≥ 90)	-	-	1	-	-	-	1	-	-	-	-	-	-	-
Dentist in each hospital (Person)														
1-2	1	1	4	-	13	1	20	-	-	1	1	1	-	8
3-4	-	-	1	-	2	-	3	1	-	2	-	2	1	3
5-6	2	-	-	-	1	-	3	1	-	-	-	1	1	1
7-8	-	-	-	-	1	-	1	-	-	-	-	-	-	-
Degrees of rurality														
Urban-like	3	-	3	-	6	1	13	2	-	2	-	2	2	8
Rural	-	-	2	-	3	-	5	-	-	1	1	-	-	2
Very rural	-	1	-	-	8	-	9	-	-	-	-	2	-	2

5.1.2 Characteristics of Analyzed Firms

After exclusion of the district hospitals without program implementation and those without validated numbers of affiliated dentists, there are 663 and 709 district hospitals included for efficiency measurement in this dissertation for fiscal year 2010 and 2011, respectively. As earlier mentioned, these hospitals are regarded as analyzed firms. Characteristics of these analyzed firms are summarized in the following Table 5.2.

Majority of the analyzed firms for both fiscal years are small-sized district hospitals (about 66%), followed by the medium-sized (about 22-23%) and the large-sized (about 11%). Most of the analyzed firms are also situated in the urban-like areas (around 76%) while the others are situated in rural (around 16%) and very rural (around 8%) areas. Nonetheless, care should be taken not to misinterpret that the majority of the analyzed firms are small-sized hospitals situated in urban-like areas since medium- and large-sized hospitals are more likely to be situated in urban-like areas where numbers of local residents are greater than those of rural districts. Almost all of district hospitals situated in rural and very rural areas, where numbers of local residents are smaller, are small-sized as well.

In both fiscal years, around one-third of the analyzed firms are those in the northeastern region. For all regions, most of the firms are small-sized and firms' locations are mainly in urban-like areas. Southern region has the highest number of hospitals categorized as being in very rural setting. Such categorization is predominantly on account of the South Thailand Insurgency in three southernmost provinces.

Table 5.2: District hospitals with high-cost dental prosthetic provision (included as analyzed firms) in fiscal year 2010 and 2011

Features	Fiscal year 2010 (N = 663 firms)							Fiscal year 2011 (N = 709 firms)						
	Central (142)	North (91)	Northeast (241)	East (48)	South (105)	West (36)	Total (663)	Central (146)	North (92)	Northeast (261)	East (51)	South (123)	West (36)	Total (709)
Hospital sizes (Inpatient beds):														
Small (10-30)	82 18.8%* 57.7%†	70 16.0%*	154 35.2%* 63.9%†	31 7.1%*	78 17.8%* 74.3%†	22 5.0%*	437 100.0%* 65.9%†	86 18.3%* 58.9%†	70 14.9%*	168 35.7%* 64.4%†	32 6.8%*	93 19.7%* 75.6%†	22 4.7%*	471 100.0%* 66.4%†
Medium (60)	43 28.5%* 30.3%†	11 7.3%*	56 37.1%* 23.2%†	8 5.3%*	21 13.9%* 20.0%†	12 7.9%*	151 100.0%* 22.8%†	43 27.4%* 29.5%†	12 7.6%*	59 37.6%* 22.6%†	9 5.7%*	23 14.6%* 18.7%†	11 7.0%*	157 100.0%* 22.2%†
Large (≥ 90)	17 12.0%†	10	31 12.9%†	9	6 5.7%†	2	75 11.3%†	17 11.6%†	10	34 13.0%†	10	7 5.7%†	3	81 11.4%†
Degrees of rurality:														
Urban-like	134 26.4%* 94.4%†	59 11.6%*	180 35.4%* 74.7%†	44 8.7%*	65 12.8%* 61.9%†	26 5.1%*	508 100.0%* 76.6%†	138 25.6%* 94.5%†	59 10.9%*	200 37.0%* 76.6%†	47 8.7%*	70 13.0%* 56.9%†	26 4.8%*	540 100.0%* 76.2%†
Rural	7 6.6%* 4.9%†	16 15.1%*	54 50.9%* 22.4%†	3 2.8%*	21 19.8%* 20.0%†	5 4.7%*	106 100.0%* 16.0%†	7 6.4%* 4.8%†	15 13.8%*	54 49.5%* 20.7%†	3 2.8%*	25 22.9%* 20.3%†	5 4.6%*	109 100.0%* 15.4%†
Very rural	1 0.7%†	16	7 2.9%†	1	19 18.1%†	5	49 7.4%†	1 0.7%†	18	7 2.7%†	1	28 22.8%†	5	60 8.5%†

*Percentage by row, †Percentage by column

5.1.3 Characteristics of Labor Input

In production of the high-cost dental prosthetic service, dentists play the major role in every step of the whole dental prosthetic service production process–from history taking and oral diagnosis, decision making to provide the service, providing clinical procedures, assigning dental laboratory procedures and dental work piece checking, and post-insertion follow-up. Since provision of the high-cost dental prosthetic service importantly depends on dentist as mentioned, only number of dentists in each firm is thus taken into efficiency analysis and regarded as labor input (x_1) in the DEA model. Labor structure of analyzed firms in fiscal year 2010 and 2011 is summarized in Table 5.3. Summary statistics of the labor structure are also summarized in the following Table 5.4.

In fiscal year 2010, up to 83.4% of all firms possessed only around 1 to 4 dentists. Nearly half of all firms had only 1 or 2 dentists. These features clearly indicate that most of the firms are quite small in terms of labor input. The greatest number of labor input was 10. Median values of labor input were around 3 in all regions, except for the Northeast and South which had median labor input of 2.

For fiscal year 2011, firms with 1 to 4 affiliated dentists were still the most common but with markedly decrease in percentage to 78.5. Unlike fiscal year 2010, the number of firms with 1 to 2 (277 firms) was slightly less than that of firms with 3 to 4 dentists (279 firms). In addition, there were 4 firms which possessed 11 to 12 dentists. Median values of labor input of nearly all regions remained the same, except for the Northeast and South which had higher values than previous year. The interquartile ranges in the Central and West were also increased.

Table 5.3: Labor structure of analyzed firms in fiscal year 2010 and 2011

Labor structure	Fiscal year 2010 (N = 663 firms)							Fiscal year 2011 (N = 709 firms)						
	Central (142)	North (91)	Northeast (241)	East (48)	South (105)	West (36)	Total (663)	Central (146)	North (92)	Northeast (261)	East (51)	South (123)	West (36)	Total (709)
Dentist in each hospital (person)														
1-2	50 16.0%* 35.2%†	37 11.9%*	131 42.0%* 54.4%†	22 7.1%*	58 18.6%* 55.2%†	14 4.5%*	312 100%* 47.1%†	41 14.8%* 28.1%†	34 12.3%*	126 45.5%* 48.3%†	14 5.1%*	51 18.4%* 41.5%†	11 4.0%*	277 100%* 39.1%†
3-4	59 24.5%* 41.5%†	41 17.0%*	75 31.1%* 31.1%†	16 6.6%*	34 14.1%* 32.4%†	16 6.6%*	241 100%* 36.3%†	62 22.2%* 42.5%†	40 14.3%*	89 31.9%* 34.1%†	26 9.3%*	49 17.6%* 39.8%†	13 4.7%*	279 100%* 39.4%†
5-6	22 15.5%†	10	24 10.0%†	7	12 11.4%†	5	80 12.1%†	26 25.2%* 17.8%†	13 12.6%*	35 34.0%* 13.4%†	5 4.9%*	14 13.6%* 11.4%†	10 9.7%*	103 100%* 14.5%†
7-8	6 4.2%†	3	10 4.1%†	3	-	1	23 3.5%†	9 6.2%†	4	10 3.8%†	4	7 5.7%†	1	35 4.9%†
9-10	5 3.5%†	-	1 0.4%†	-	1 1.0%†	-	7 1.1%†	6 4.1%†	1	1 0.4%†	2	-	1	11 1.6%†
11-12	-	-	-	-	-	-	-	2 1.4%†	-	-	-	2 1.6%†	-	4 0.6%†

*Percentage by row, †Percentage by column

Table 5.4: Summary statistics of labor input represented by number of dentists in each analyzed firm in fiscal year 2010 and 2011

Summary statistics	Fiscal year 2010 (N = 663 firms)							Fiscal year 2011 (N = 709 firms)						
	Central (142)	North (91)	Northeast (241)	East (48)	South (105)	West (36)	Total (663)	Central (146)	North (92)	Northeast (261)	East (51)	South (123)	West (36)	Total (709)
Maximum	10	8	9	8	10	8	10	12	9	10	9	12	10	12
Minimum	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Range	9	7	8	7	9	7	9	11	8	9	8	11	9	11
Median	3	3	2	3	2	3	3	3	3	3	3	3	3	3
IQR	2	2	2	2	2	2	2	3	2	2	2	2	3	2

IQR = Interquartile range

5.1.4 Characteristics of Operating Expenses

Operating expenses are collectively represented by reimbursement value of each firm in this dissertation. The reimbursement value is thus regarded as production input of operating expenses (x_2) in the DEA model. Since reimbursement values are collected from two different past fiscal years–2010 and 2011, these values are then adjusted to be present values of 2012 which is the time of this dissertation. The value adjustment is undertaken using Inflation Adjustment Factor (IAF); which is derived from provincial-specific consumer price index (CPI)–taking also variation in price level change among different provinces into account. Such adjustment allows comparisons of respective reimbursement values occurred at different times. This fashion is in accordance with the concept of time value of money, which is generally expressed as “A dollar today is worth more than a dollar tomorrow”. The value of a dollar today is greater than a dollar tomorrow because the money has interest-earning potential or time value of money characteristic. The dollar can be invested and earn a future’s interest which makes the total accumulate of a value of the invested dollar more than a dollar by tomorrow.

Summary statistics of operating expenses, represented by reimbursement values expressed in Thai Baht, in fiscal year 2010 and 2011 are presented in the following Table 5.5. Reimbursement values can be viewed as real monetary values specific for context of each fiscal year of analysis. Nonetheless, as earlier explained, present values presented alongside their corresponding reimbursement values are adjusted monetary values to the year 2012. Thus, these present values allow comparison across the two fiscal years.

In fiscal year 2010, total reimbursement value of all 663 analyzed firms was 119,214,773.8 THB (present value = 129,634,014.7 THB). National mean reimbursement value and its corresponding present value were as high as around 179,811 and 195,526 THB, respectively. Mean reimbursement value in central region was exceptionally far greater than the values of other regions while that of southern region was the lowest. Dispersion of reimbursement values from their corresponding mean value in each region was quite similar for all regions, except for the central region which exhibited the far greatest standard deviation in reimbursement values. Maximum reimbursement of a firm in central region was the highest and this also defined the highest in the nation.

Total reimbursement value of all 709 analyzed firms in fiscal year 2011 was 161,155,845.4 THB (present value = 166,558,375.6 THB). The national mean reimbursement and its present value were about 227,300 and 234,920 THB, respectively. These values were noticeably higher than those of the previous year. Characteristics of regional mean reimbursement values were quite comparable to the previous year, with the highest mean in the Central and the lowest mean in the South. When mean present values of reimbursement were compared between these two years, increase in average present values could be indicated for all regions and at national level. This feature implied average growth in monetary value of service reimbursement. Payer explains that this reimbursement growth was due to greater amount of budget allocated to this service in 2011. Dispersion of reimbursement values from the regional mean was still found remarkably the highest in the group of firms in the central regions, while standard deviations of such values among all other firms were quite comparable and apparently lower than that of the Central.

Table 5.5: Summary statistics of operating expenses (in Thai Baht) in fiscal year 2010 and 2011

Summary statistics:	Maximum RV†	Maximum PV*	Minimum RV†	Minimum PV*	Range RV†	Range PV*	Mean RV†	Mean PV*	SD RV†	SD PV*
Fiscal year 2010										
Central	930,400.0	992,289.1	1,040.0	1,105.4	929,360.0	991,183.7	240,955.5	261,120.7	185,870.8	201,896.6
North	555,000.5	602,653.0	16,205.0	17,567.6	538,795.5	585,085.4	177,128.0	191,752.4	120,139.6	129,601.9
Northeast	565,400.0	656,594.9	2,080.0	2,310.2	563,320.0	654,284.7	184,016.1	200,568.1	116,855.4	128,763.2
East	537,240.0	592,170.8	6,150.0	6,713.3	531,090.0	585,457.6	161,011.9	174,299.8	111,900.2	121,762.5
South	810,502.5	905,656.2	3,520.0	3,857.0	806,982.5	901,799.2	116,943.3	128,404.2	106,106.0	117,831.9
West	451,269.0	494,324.6	4,400.0	4,713.4	446,869.0	489,611.2	125,693.1	136,657.4	90,732.5	99,213.7
National	930,400.0	992,289.1	1,040.0	1,105.4	929,360.0	991,183.7	179,811.1	195,526.4	137,787.1	150,334.6
Fiscal year 2011										
Central	1,192,615.0	1,221,197.8	1,500.0	1,556.1	1,191,115.0	1,219,641.7	313,616.5	324,183.0	237,274.9	245,533.8
North	790,635.0	832,306.9	1,200.0	1,217.0	789,435.0	831,090.0	223,129.0	228,061.3	162,869.3	167,072.7
Northeast	840,270.0	866,659.4	12,000.0	12,276.6	828,270.0	854,382.7	221,354.4	229,100.4	153,887.5	159,519.5
East	515,825.0	538,941.1	1,500.0	1,563.1	514,325.0	537,377.9	183,947.1	190,476.0	134,446.6	139,215.9
South	1,033,790.0	1,076,587.5	7,300.0	7,515.4	1,026,490.0	1,069,072.1	169,470.2	175,664.8	156,103.7	161,924.7
West	689,665.0	727,803.2	12,700.0	12,981.7	676,965.0	714,821.6	190,009.3	198,049.8	135,477.7	142,628.4
National	1,192,615.0	1,221,197.8	1,200.0	1,217.0	1,191,415.0	1,219,980.8	227,300.2	234,920.1	179,883.3	186,158.2

†Reimbursement value, *Present value (= Reimbursement value adjusted by inflation adjustment factor, IAF)

5.1.5 Characteristics of Production Outputs

As earlier mentioned, there are 4 production outputs defined for efficiency analysis in this dissertation; comprising single denture (y_1), complete denture (y_2), partial denture with ≤ 5 replaced teeth (y_3), and partial denture with > 5 replaced teeth (y_4). The production output y_1 and y_2 are dental prostheses used for full arch replacement of teeth for single dental arch and both dental arches, respectively. The production output y_3 and y_4 are dental prostheses used for partial arch replacement of teeth which differ in numbers of replaced teeth. In this context of analysis, the counting unit for complete denture (y_2) is 'set' while the counting unit similarly used for all other output categories is 'piece'. Set is used as counting unit of complete denture to represent two pieces of maxillary and mandibular complete denture. The following Table 5.6 provides summary statistics of the first two production outputs (y_1 and y_2) for both fiscal years. Summary statistics of the other two production outputs (y_3 and y_4) are later provided in Table 5.7.

According to Table 5.6, very little difference in national mean values of single denture production was found between the two fiscal years. The national median value of 4 pieces indicated that firms averagely serviced not more than a piece of single denture per month. Nonetheless, single denture provision varied greatly across firms as shown by considerable national values of interquartile ranges–9 in 2010 and 10 in 2011. In 2010, the highest regional maximum of single denture provision was found in a firm in southern region with 227 pieces per year (about 19 pieces per month), followed by the maximum values in central and northeastern regions – 196 and 137 pieces per year, respectively. Nonetheless, in the latter fiscal year, the maximum single denture provision in the South dramatically decreased to only 51

pieces per year. The maximal single denture provision in central, eastern, and western regions also noticeably declined.

Complete denture is a very important category of the dental prosthetic service since it involves the most complicated fabrication procedures, requires highest cost of service production, and is needed to restore oral functions among patients with total loss of teeth. From Table 5.6, national median values of complete denture production were around 25 to 27 sets per year or slightly more than 2 sets per month for each firm. However, there were still some firms which did not provide complete denture through the program. Maximum complete denture provision was found highest at 226 sets per year, or about 19 cases per month, by a firm in central region in 2011.

According to the following Table 5.7, in both categories of partial dentures, there were some firms which did not provide the partial denture service through the program. For partial denture with ≤ 5 replaced teeth, national medians of provision were nearly the same at around 14-15 pieces per year for both fiscal years. Each region also showed slight increase in regional medians of provision, except for the Northeast, when two years were compared. Nonetheless, region medians varied greatly across different regions with the same pattern for both fiscal years–ranging from the lowest median of 0 in the South to the highest median of 27 in the Northeast.

For partial denture with > 5 replaced teeth, national and all regional medians tended to be greater in 2011, except for decrease in provision in the East and the South. However, great variation in regional medians across different regions still existed. The national median of provision in this category has increased from 9 pieces per year in 2010 to 12 pieces per year in 2011. Nonetheless, these figures indicated that rate of provision was still as low as about 1 piece per month.

Table 5.6: Summary statistics of production outputs comprising single denture and complete denture in fiscal year 2010 and 2011

Summary statistics:	Single denture (piece)					Complete denture (set)				
	Maximum	Minimum	Range	Median	IQR	Maximum	Minimum	Range	Median	IQR
Fiscal year 2010										
Central	196	0	196	4	11	175	0	175	37	40
North	50	0	50	7	9	100	0	100	24	31
Northeast	137	0	137	5	8	112	0	112	23	24
East	45	0	45	2.5	8	106	1	105	31.5	34
South	227	0	227	1	4	106	0	106	20	23
West	37	0	37	2	5	101	1	100	21	22
National	227	0	227	4	9	175	0	175	25	30
Fiscal year 2011										
Central	157	0	157	5	14	226	0	226	41	43
North	94	0	94	6.5	10	167	0	167	24.5	30
Northeast	163	0	163	6	9	160	0	160	22	27
East	36	0	36	2	5	100	0	100	27	32
South	51	0	51	1	4	142	0	142	25	27
West	25	0	25	1.5	8	110	0	110	26	28
National	163	0	163	4	10	226	0	226	27	34

IQR = Interquartile range

Table 5.7: Summary statistics of production outputs comprising partial dentures with ≤ 5 replaced teeth and with > 5 replaced teeth in fiscal year 2010 and 2011

Summary statistics:	Partial denture with ≤ 5 replaced teeth (piece)					Partial denture with > 5 replaced teeth (piece)				
	Maximum	Minimum	Range	Median	IQR	Maximum	Minimum	Range	Median	IQR
Fiscal year 2010										
Central	164	0	164	8	29	121	0	121	10	30
North	188	0	188	21	40	82	0	82	11	23
Northeast	184	0	184	27	44	101	0	101	14	26
East	60	0	60	4	18	65	0	65	5.5	18
South	185	0	185	0	10	75	0	75	2	8
West	68	0	68	9	21	58	0	58	5.5	15
National	188	0	188	14	34	121	0	121	9	23
Fiscal year 2011										
Central	139	0	139	13	36	172	0	172	14	33
North	161	0	161	23.5	36	129	0	129	13	21
Northeast	194	0	194	27	38	124	0	124	20	29
East	52	0	52	5	19	62	0	62	5	17
South	183	0	183	1	9	132	0	132	1	9
West	66	0	66	12	19	70	0	70	10	20
National	194	0	194	15	34	172	0	172	12	26

IQR = Interquartile range

5.2 Results of Efficiency Measurement and Related Factors

5.2.1 Empirical Results of Technical and Scale Efficiency Measurement

Technical efficiency scores of firms in this context of analysis are calculated from the input-oriented VRS DEA Model (see Chapter III, section 3.2 for theoretical foundation of this model; and see Chapter IV, section 3.1.4 (A) and (B) for model specification). The input-oriented technical efficiency score (TE_i) has a value of $0 \leq TE_i \leq 1$. When TEi is equal to 1, this implies that the analyzed firm is technically efficient. The closer technical efficiency score gets to 0, the less technical efficiency is indicated. Technical efficiency score measured under assumption of CRS, or TE^{CRS}, is regarded as overall technical efficiency. Technical efficiency score alternatively measured under assumption of VRS, or TE^{VRS}, is instead recognized as pure technical efficiency or technical efficient which is not confounded by scale efficiency. Scale efficiency score of each firm is thus calculated using the following relationship written in equation form as:

$$SE_i = TE_i^{CRS} / TE_i^{VRS}$$

Details of this equation have been previously discussed in Chapter III, section 3.2 (B). Similar to interpretation of technical efficiency score, scale efficiency score of 1 indicates scale efficiency while score of less than 1 instead implies scale inefficiency.

Table 5.8 provides summary statistics of input-oriented technical and scale efficiency measures of analyzed firms in both fiscal years. Efficiency scores of each firm identified in this analysis well reflect the previously mentioned relationship that overall technical efficiency is the product between its pure technical efficiency and scale efficiency. Since VRS assumption of analysis is specified–based on applicability to analysis of not-for-profit healthcare firms, pure technical efficiency is thus of great

focus here. In fiscal year 2010; mean scores of overall technical efficiency, pure technical efficiency, and scale efficiency are 0.58, 0.69, and 0.84, respectively. Since efficiency analysis in this context is an input-oriented analysis, the mean value of pure technical efficiency, 0.69, thus implies that averagely the analyzed firms can still reduce their consumption of all service production inputs by about 30% while maintaining the same level of service outputs. Number of efficient firms as revealed by pure technical efficiency score equal to 1 was 133 or about 20% of all analyzed firms. This means that up to 80% of the analyzed firms still have some degree of inefficiency in production of the service. In other words, there are still considerable possibilities to improve efficiency in provision of the high-cost dental prosthetic service in terms of optimal use of resource inputs. Overall technical efficiency can also be improved averagely by 42%, by means of reduction in pure technical inefficiency–optimizing consumption of service production inputs, and operation at optimal scale–optimal use of service production inputs to yield the highest service productivity. Strategies to reduce pure technical inefficiency can be suggested by lessons learned from best practice firms, which is later discussed in qualitative study results.

In fiscal year 2011, mean values of all efficiency measures are quite comparable to those of the previous fiscal year, with slight decrease in mean scores of overall and pure technical efficiency and slight increase in mean score of scale efficiency. Average value of pure technical efficiency scores, 0.65, implies that all analyzed firms in this fiscal year can still reduce their consumption of all service production inputs by 35% on average. Numbers of efficient firms in all categories of efficiency have been declined from the previous year. There are 109 efficient firms or

about 15% of all analyzed firms which are assessed to be technically efficient under VRS assumption. This finding also implies that up to 85% of the analyzed firms still have some degree of pure technical inefficiency which can be improved by reduction in consumption of resource inputs. Overall technical inefficiency can still be decreased by 46% averagely through, as earlier mentioned, reduction in pure technical inefficiency and optimal scale operation.

These empirical results of both fiscal years consistently lead to 2 crucial remarks. First, there is still great feasibility to improve technical efficiency among firms providing the high-cost dental prosthetic service since some extent of technical inefficiency can apparently be indicated in this analysis. Second, not only the pure technical inefficiency, but also scale inefficiency that evidently contribute to overall technical inefficiency in service provision.

To further provide practical policy guideline regarding scale of service provision, additional analysis to clarify the previously identified scale inefficiency is undertaken. Since scale inefficiency can be due to existence of either decreasing or increasing returns to scale, constraint of non-increasing returns to scale (NIRS) is additionally imposed to the DEA model–to substitute restriction of $N1'\boldsymbol{\lambda} = 1$ by $N1'\boldsymbol{\lambda} \leq 1$. Once the NIRS TE score is calculated to be unequal to TE^{VRS}, then increasing returns to scale can be detected. If these measures are equal, decreasing returns to scale is instead indicated. In the lower part of Table 5.8, numbers and percentages of firms with existence of increasing returns to scale, optimal scale, and decreasing returns to scale for each fiscal year are summarized respectively. In both fiscal years, more than half of the analyzed firms exhibit existence of increasing returns to scale.

In other words, these firms operated below their optimal scale. This additional analysis yields more firms with scale efficiency than the previous model by recognizing firms with SE = 0.999 to have scale efficiency. The other firms with existence of decreasing returns to scale operated above their optimal scale. Since most of the firms with scale inefficiency operated below their optimal scale, an appropriate strategy to gain the greatest increase in overall technical efficiency could be accomplished through elimination of increasing returns to scale problem. This implies that expansion in scale of operation in a certain firm which exhibited increasing returns to scale would yield better service productivity. Alternatively, increase in overall technical efficiency can also be achieved through downsizing of the operation in firms exhibiting decreasing returns to scale. For instance, from policy maker's point of view, firms with excessive facility related to dental prosthetic service relative to their real service burden should improve scale of operation to suit appropriate extent of service provision. Nonetheless, downsizing strategy could result in lesser improvement in overall technical efficiency since firms with problem of decreasing returns to scale are of much smaller portion of all firms. Applying both strategies to their correspondingly suitable firms can therefore be the best policy option. Above all, since this study is a pioneering efficiency analysis which considers only a service item from the whole lists of dental services provided at district hospitals–based on applicability of DEA to activity-based analysis, the mentioned strategies related to exploitation of scale economies could consequently be viewed only as theoretical suggestions. Comprehensive efficiency analysis of all dental services is needed before making practical policy guidelines related to scale economies.

Table 5.8: Summary statistics of input-oriented technical efficiency measures of firms providing the high-cost dental prosthetic service in Thailand in fiscal year 2010 and 2011

Summary statistics	Fiscal year 2010 (663 firms)			Fiscal year 2011 (709 firms)		
	Overall technical efficiency	Pure technical efficiency	Scale efficiency	Overall technical efficiency	Pure technical efficiency	Scale efficiency
Maximum	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.22	0.27	0.29	0.11	0.27	0.11
Range	0.78	0.73	0.71	0.89	0.73	0.89
Mean	0.58	0.69	0.84	0.54	0.65	0.87
SD	0.20	0.21	0.16	0.17	0.19	0.15
Number of efficient firms	25	133	43	17	109	32

Operating scale	Increasing returns to scale	Optimal scale	Decreasing returns to scale	Increasing returns to scale	Optimal scale	Decreasing returns to scale
Number of firms	462 69.7%*	50 7.5%*	151 22.8%*	403 56.8%*	36 5.1%*	270 38.1%*

*Percentage by row

The following Table 5.9 provides characteristics of firms by their sizes and locations in different degrees of rurality, and their corresponding measures of pure technical efficiency. In fiscal year 2010, nearly up to 30% of the firms are assessed to have the efficiency scores of more than 0.80. However, the figure is remarkably decreased to 20.6% of all firms in 2011. In 2010, most of the small hospital firms have the efficiency scores of more than 0.60 while those medium- and large-sized firms mostly have the scores of 0.41 to 0.60. These characteristics of efficiency scores among medium and large firms are repeated in the latter fiscal year while most of the small firms have their efficiency scores shifted down to the range of 0.41 to 0.60. Regarding efficiency of firms in various degrees of rurality, most of the firms in urban-like areas have moderate efficiency scores of 0.41 to 0.60 while those in rural and very rural areas have relatively high efficiency scores of 0.81 and more in fiscal year 2010. Nonetheless, in the latter fiscal year, most of the firms in all degrees of rurality have only moderate level of efficiency scores.

The latter Table 5.10 and Table 5.11 additionally provide details of firms' regional locations and labor inputs, and corresponding pure technical efficiency scores. In 2010, major groups of firms in different regions tend to have different ranges of efficiency scores. Unlike the previous year, major groups of firms in all regions tend to have the same range of moderate efficiency scores (0.41-0.60) in 2011. Regarding efficiency of firms with different labor inputs in both fiscal years, most of the firms with only 1-2 dentists tend to have high efficiency scores of 0.61 and more, while most of the firms with more numbers of dentists instead have moderate efficiency scores of 0.41-0.60.

According to 5.9-5.11, average pure technical efficiency score is also provided for each category of interest. In the aspect of difference in hospital size, smaller (10-30 beds) hospitals showed highest average value of pure technical efficiency score. Decreasing trend in average values of pure technical efficiency score can also be observed in the groups of hospitals with larger sizes.

In the aspect of different degrees of rurality, an increasing trend of average values of pure technical efficiency is unexpectedly revealed. From the empirical results, hospitals situated in the areas with more degree of hardship tended to have higher pure technical efficiency averagely, although the difference in such values was not considerable. Nevertheless, it should be kept in mind that the firms included in analysis at this stage are those with service provision through the program only and the considerable numbers of hospitals situated in rural and very rural areas have been previously excluded due to no service provision through this program.

When average values of pure technical efficiency scores are compared across different regions of Thailand, difference among these values can be observed. Nonetheless, magnitude of such difference is not considerable. In other words, average values of pure technical efficiency scores across different geographical regions of Thailand regarding this dental service are quite comparable.

In the aspect of labor input, firms with lower numbers of affiliated dentists tended to have higher pure technical efficiency scores on average. This evidence suggests that adding more and more numbers of dentists does not necessarily increase pure technical efficiency in provision of the high-cost dental prosthetic service.

Table 5.9: Characteristics of firms by sizes, degrees of rurality and pure technical efficiency measures in fiscal year 2010 and 2011

Features	Pure technical efficiency measures in fiscal year 2010						Pure technical efficiency measures in fiscal year 2011					
	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total
Overall	0.69	44	212	212	195	663	0.65	44	305	214	146	709
		6.6%*	32.0%*	32.0%*	29.4%*	100.0%*		6.2%*	43.0%*	30.2%*	20.6%*	100.0%*
Hospital sizes (inpatient beds)												
Small (10-30)	0.72	15	121	149	152	437	0.67	16	205	137	113	471
		3.4%*	27.7%*	34.1%*	34.8%*	100.0%*		3.4%*	43.5%*	29.1%*	24.0%*	100.0%*
			57.1%†	70.3%†	77.9%†	65.9%†			67.2%†	64.0%†	77.4%†	66.4%†
Medium (60)	0.62	13	64	48	26	151	0.61	15	65	54	23	157
		8.6%*	42.4%*	31.8%*	17.2%*	100.0%*		9.6%*	41.4%*	34.4%*	14.6%*	100.0%*
			30.2%†	22.6%†	13.3%†	22.8%†			21.3%†	25.2%†	15.8%†	22.2%†
Large (≥ 90)	0.61	16	27	15	17	75	0.58	13	35	23	10	81
			12.7%†	7.1%†	8.7%†	11.3%†			11.5%†	10.7%†	6.8%†	11.4%†
Degrees of rurality												
Urban-like	0.68	39	169	163	137	508	0.63	35	240	167	98	540
		7.7%*	33.3%*	32.1%*	27.0%*	100.0%*		6.5%*	44.4%*	30.9%*	18.1%*	100.0%*
			79.7%†	76.9%†	70.3%†	76.6%†			78.7%†	78.0%†	67.1%†	76.2%†
Rural	0.74	2	30	37	37	106	0.69	7	41	30	31	109
		1.9%*	28.3%*	34.9%*	34.9%*	100.0%*		6.4%*	37.6%*	27.5%*	28.4%*	100.0%*
			14.2%†	17.5%†	19.0%†	16.0%†			13.4%†	14.0%†	21.2%†	15.4%†
Very rural	0.74	3	13	12	21	49	0.70	2	24	17	17	60
			6.1%†	5.7%†	10.8%†	7.4%†			7.9%†	7.9%†	11.6%†	8.5%†

*Percentage by row, †Percentage by column / PTE = Pure Technical Efficiency

Table 5.10: Characteristics of firms by geographical regions and pure technical efficiency measures in fiscal year 2010 and 2011

Features	Pure technical efficiency measures in fiscal year 2010						Pure technical efficiency measures in fiscal year 2011					
	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total
Geographical regions												
Central	0.68	14 9.9%* 	36 25.4%* 17.0%†	51 35.9%* 24.1%†	41 28.9%* 21.0%†	142 100.0%* 21.4%†	0.66	10 6.8%* 	54 37.0%* 17.7%†	50 34.2%* 23.4%†	32 21.9%* 21.9%†	146 100.0%* 20.6%†
North	0.70	1 	32 15.1%†	34 16.0%†	24 12.3%†	91 13.7%†	0.65	1 	41 13.4%†	33 15.4%†	17 11.6%†	92 13.0%†
Northeast	0.74	5 2.1%* 	72 29.9%* 34.0%†	73 30.3%* 34.4%†	91 37.8%* 46.7%†	241 100.0%* 36.3%†	0.68	7 2.7%* 	104 39.8%* 34.1%†	84 32.2%* 39.3%†	66 25.3%* 45.2%†	261 100.0%* 36.8%†
East	0.62	6 	17 8.0%†	18 8.5%†	7 3.6%†	48 7.2%†	0.56	6 	29 9.5%†	11 5.1%†	5 3.4%†	51 7.2%†
South	0.65	13 12.4%* 	40 38.1%* 18.9%†	29 27.6%* 13.7%†	23 21.9%* 11.8%†	105 100.0%* 15.8%†	0.60	16 13.0%* 	58 47.2%* 19.0%†	28 22.8%* 13.1%†	21 17.1%* 14.4%†	123 100.0%* 17.3%†
West	0.62	5 	15 7.1%†	7 3.3%†	9 4.6%†	36 5.4%†	0.60	4 	19 6.2%†	8 3.7%†	5 3.4%†	36 5.1%†

*Percentage by row, †Percentage by column / PTE = Pure Technical Efficiency

Table 5.11: Characteristics of firms by their labor inputs and pure technical efficiency measures in fiscal year 2010 and 2011

Features	Pure technical efficiency measures in fiscal year 2010						Pure technical efficiency measures in fiscal year 2011					
	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total	Average PTE	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	Total
Number of dentists (person)												
1-2	0.81	-	39 12.5%* 18.4%†	129 41.3%* 60.8%†	144 46.2%* 73.8%†	312 100.0%* 47.1%†	0.77	-	77 27.8%* 25.2%†	89 32.1%* 41.6%†	111 40.1%* 76.0%†	277 100.0%* 39.1%†
3-4	0.61	15 6.2%*	122 50.6%* 57.5%†	65 27.0%* 30.7%†	39 16.2%* 20.0%†	241 100.0%* 36.3%†	0.59	12 4.3%*	159 57.0%* 52.1%†	86 30.8%* 40.2%†	22 7.9%* 15.1%†	279 100.0%* 39.4%†
5-6	0.52	19	40 18.9%†	12 5.7%†	9 4.6%†	80 12.1%†	0.56	18 17.5%*	47 45.6%* 15.4%†	29 28.2%* 13.6%†	9 8.7%* 6.2%†	103 100.0%* 14.5%†
7-8	0.53	6	11 5.2%†	4 1.9%†	2 1.0%†	23 3.5%†	0.51	10	15 4.9%†	8 3.7%†	2 1.4%†	35 4.9%†
9-10	0.53	4	-	2 0.9%†	1 0.5%†	7 1.1%†	0.55	3	5 1.6%†	1 0.5%†	2 1.4%†	11 1.6%†
11-12	-	-	-	-	-	-	0.47	1	2 0.7%†	1 0.5%†	-	4 0.6%†

*Percentage by row, †Percentage by column / PTE = Pure Technical Efficiency

As mentioned earlier, one way to improve overall technical efficiency in provision of the dental service is through reduction in pure technical inefficiency. To eliminate such inefficiency, excessive use of service production inputs is needed to be cut down. Thus information regarding the excessive use of inputs or input slacks in production is a key to further action. Input slacks in production of the high-cost dental prosthetic service in this context of analysis can be divided into 2 categories comprising labor input slack and slack in operating expenses. Table 5.12 provides characteristics of firms with input slacks for both fiscal years. Even though a certain firm can theoretically have both labor input slack and slack in operating expenses, empirical results in this analysis instead indicate the significant ones for each firm. Thus, firms with labor input slack and those with slack in operating expenses in each fiscal year are mutually exclusive. Although analysis of input slacks is separately undertaken for each fiscal year, the results of input slacks of both fiscal years are very consistent. Although the greatest numbers of firms with existence of labor input slack belong to the group of small hospital firms in both years–31 firms in 2010 and 23 in 2011, the largest proportions instead belong to the group of large hospital firms–12 out of 75 firms in 2010 and 16 from 81 firms in 2011. Thus larger firms are more likely to be found having labor input slack. Labor input slack is also found greatest in proportion of firms located in very rural areas in both years–5 out of 49 firms in 2010 and 5 from 60 in 2011. However, such result should not be misinterpreted that firms in very rural areas are more likely to have excessive inputs of dentists. Instead, such finding should be cautiously interpreted as that, considering only one item of all dental services provided by local firms, firms located in very rural areas have slightly

greater proportion of those having more than optimal labor inputs given their recent delivery extent of this specific service. Labor input slack can also be found in some firms of all regions. This input slack is found largest in proportion among firms in the western region for both fiscal years.

In both fiscal years, firms with slack in operating expenses are found in greatest proportion in the group of small-sized firms, as indicated by the greatest proportions of 69 out of 437 small firms in 2010 and 71 from 471 in 2011. In fiscal year 2010, firms located in very rural areas show the greatest tendency of having slack in operating slacks compared to those located in areas of different level of rurality. Firms located in the southern regions also show the greatest likelihood of having such input slack compared to firms located in all other regions. Nonetheless, in the latter fiscal year of 2011, firms located in rural and very rural areas are comparable in likelihood of having this kind of slack compared to the remarkably lower proportion in the group of firms located in urban-like areas. Firms located in the northeastern region are also found to have greatest proportion of firms having this kind of input slack in this year.

Table 5.13 provides summary statistics of the input slacks. Since this is an input-oriented analysis, all statistics consequently imply excess in inputs which could be minimized to improve pure technical efficiency. Also note that monetary value of operating expenses here is represented by the adjusted present value of 2012, not the unadjusted reimbursement value, to allow sound comparison across fiscal years. Major finding is that there is an apparent growth in both kinds of input slacks in fiscal year 2011 which is consistent with finding of decrease in average pure technical efficiency measure.

Table 5.12: Characteristics of firms with input slacks in production of high-cost dental prosthetic service in fiscal year 2010 and 2011

Summary statistics	Fiscal year 2010 (Total 663 firms)		Fiscal year 2011 (Total 709 firms)	
	Labor input slack (59 firms, 8.9%)	Slack in operating expenses (75 firms, 11.3%)	Labor input slack (55 firms, 7.8%)	Slack in operating expenses (77 firms, 10.9%)
Hospital sizes (inpatient beds)				
Small (10-30 beds)	31	69	23	71
Medium (60)	16	5	16	5
Large (90 and more)	12	1	16	1
Degrees of rurality				
Urban-like	48	39	43	43
Rural	6	23	7	22
Very rural	5	13	5	12
Geographical regions				
Central	17	9	13	6
North	9	9	9	7
Northeast	17	33	25	43
East	1	3	1	4
South	10	16	2	14
West	5	5	5	3

Note: Firms with labor input slack and those with slack in operating expenses in each fiscal year are mutually exclusive.

Table 5.13: Summary statistics of input slacks identified in some of the firms providing the high-cost dental prosthetic service in Thailand in fiscal year 2010 and 2011

Summary statistics	Fiscal year 2010		Fiscal year 2011	
	Labor input slack (59 firms)	Slack in operating expenses (75 firms)	Labor input slack (55 firms)	Slack in operating expenses (77 firms)
Maximum	4.68	23,674.09	6.86	79,573.64
Minimum	0.02	173.68	0.01	324.84
Range	4.66	23,500.41	6.85	79,248.8
Mean	0.80	8,423.44	1.28	27,237.04
SD	0.90	5,811.77	1.45	20,823.19

5.2.2 Investigating Factors Related to Technical Efficiency

To further investigate factors related to pure technical efficiency by means of Tobit regression analysis, parameters related to explanatory variables and pure technical efficiency scores of all analyzed firms in both of the fiscal years are pooled together into the model. Consequently, the Tobit model analyzes such relationship from the total number of 1,372 firms. Three explanatory variables of interest include hospital size–as indicated by numbers of inpatient bed, number of affiliated dentists in each firm, and location of firms in central region against locations in all other regions combined.

Table 5.14 summarizes results of the Tobit regression analysis. The empirical results reveal highly significant relationship of all interested explanatory variables and the outcome of pure technical efficiency scores. Hospital size and location of firms in the central region have positive effect on pure technical efficiency. This means that larger hospital sizes can achieve higher pure technical efficiency compared to the smaller ones. Location of firms in the central region of the nation can also bring about higher pure technical efficiency in provision of the high-cost dental prosthetic service compared to locations in all other regions of the nation. In contrast, numbers of firms' affiliated dentists instead show negative effect on the pure technical efficiency scores. This implies that growing numbers of affiliated dentists can adversely result in lower pure technical efficient scores. Nonetheless, values of beta coefficients found for all explanatory variables are relatively small, implying low contribution of these explanatory variables in predicting the outcome variable.

Table 5.14: Tobit analysis using pure technical efficiency scores as dependent variable

Explanatory variables	Beta coefficient	Standard error	P-value	95% CI
Constant	0.8830	0.0126	< 0.001	0.8583 - 0.9076
Hospital size	0.0008	0.0003	0.001	0.0003 - 0.0013
Number of dentists	- 0.0758	0.0037	< 0.001	-0.0832 - -0.0685
Location in central region	0.0482	0.0137	< 0.001	0.0213 - 0.0752

5.3 Results of Qualitative Phase of Study

In attempt to generate managerial lessons from best practice dental units which efficiently provide the high-cost dental prosthetic service in both fiscal year 2010 and 2011, qualitative study method of in-depth interview has been applied to gain the insight from 3 main interested persons of the dental service; comprising director of the district hospital or his representative, representative dentist, and dental prosthetic service recipients. In this phase of study, there are 3 selected best practice district hospitals based mainly on their achievement in gaining exceptionally high score of pure technical efficiency in both fiscal years, considerable extent of service delivery, evidence of complete denture service provision, and eligible characteristics relevant to criteria described in research methodology section. The 3 best practice hospitals include:

- A 30-bed district hospital located in an urban-like area in a province belongs to area of Greater Bangkok Metropolitan, with 5 affiliated dentists in fiscal year 2010 and 6 affiliated dentists in 2011 (representative of small-sized district hospitals),
- A 60-bed district hospital located in an urban-like area in the southern region which is about 900 kilometers away from Bangkok, with 4 affiliated dentists in both fiscal years (representative of medium-sized district hospitals), and
- A 90-bed district hospital located in an urban-like area in the central region which is about 200 kilometers away from Bangkok, with 4 affiliated dentists in both fiscal years (representative of large-sized district hospitals).

Characteristics of key informants in each of the best practice district hospitals can be summarized as shown in the following Table 5.15.

Table 5.15: Characteristics of key informants in each best practice hospital

Best practice unit:	**Key informants:**	
	Providers	**Service recipients**
(1) Small-sized district hospital	(1) Head of dental unit (also on behalf of hospital director due to his responsibility for managing hospital's financial unit) - male dentist	(1) Female service recipient: - Complete denture (2) Female service recipient: - Maxillary and mandibular partial denture–each with > 5 replaced teeth (3) Male service recipient: - Complete denture (4) Male service recipient: - Complete denture
(2) Medium-sized district hospital	(1) Hospital director - male medical doctor (2) Head of dental unit - female dentist	(1) Female service recipient: - Maxillary and mandibular partial denture–each with > 5 replaced teeth (2) Female service recipient: - Maxillary and mandibular partial denture–each with ≤ 5 replaced teeth (3) Female service recipient: - Complete denture (4) Male service recipient: - Maxillary and mandibular partial denture–each with > 5 replaced teeth
(3) Large-sized district hospital	(1) Hospital director - male medical doctor (2) Head of dental unit - male dentist	(1) Female service recipient: - Maxillary partial denture with ≤ 5 replaced teeth (2) Female service recipient: - Complete denture (3) Female service recipient: - Maxillary single denture - Mandibular partial denture with > 5 replaced teeth (4) Female service recipient: - Complete denture (5) Male service recipient: - Maxillary partial denture with ≤ 5 replaced teeth

According to the difference in context of the selected hospitals, key issues obtained from the in-depth interview are consequently organized on case-by-case basis to reflect such difference and to allow application of these lessons learned to relevant context of local service providers.

5.3.1 Managerial Lessons Learned from Small-sized Best Practice Unit

Key informant of the small-sized best practice unit is the head dentist of dental unit of the hospital. For this study, the informant provides information on behalf of the dental unit as representative dentist. In addition, since the informant also has responsibility in managing hospital financial unit which plays important role in claim and reimbursement of this dental prosthetic service, the dentist therefore provides information related to hospital financial management policy as representative of the hospital director as well. Important managerial strategies regarding provision of the high-cost dental prosthetic service in this hospital are summarized as followed.

- **Self-assessment of service delivery extent:** Information related to extent of high-cost dental prosthetic service delivery has been well collected due to the need of claim for service reimbursement. The informant provides details of how the collected data can be used for self-assessment as followed.

  "… Such information is currently reviewed annually, mainly at the end of fiscal year, to quickly assess performance of the dental unit in providing this service. Nonetheless, we have to admit that there is still a lack of periodic review to evaluate short-run output of service provision which would promptly guide appropriate action regarding delivery of this service. This periodic

review of service extent is thus taken into account as the next step in our service development. Our dental unit also expects to expand its provision of this service in latter fiscal years since the dental unit has been allocated another dentist in fiscal year 2012 …" (Representative dentist).

- **Decentralization of service provision to sub-district Health Promoting Hospitals:** The key informant also discussed about how the hospital dental unit allocates dentists to work in community as followed.

  "… Since our hospital dental unit has only 3 dental chairs while having up to 6 dentists, all of dentists consequently need to work someday outside the hospital dental unit. Therefore, we have roster to work in sub-district Health Promoting Hospitals. Instead of providing only routine dental services–for example, dental extraction, dental filling, and others–at the sub-district hospitals; scope of our service has been extended to cover provision of the high-cost dental prosthetic service as well. This strategy has been implemented to decentralize provision of this service to sub-district facility so that we can reduce the long-waiting queue at our main hospital dental unit and to facilitate local service users. There are 4 out of 11 sub-district hospitals in this district which have been selected for this extension of service scope. We took a large number of local residents with great demand of this service into account when we selected the local facility …" (Representative dentist).

- **Setting specific working hours devoted to dental prosthetic service:** The key informant also talked about the way the dental unit allocates its working hours to this service as followed.

  "… Total period from the first visit of oral examination to delivery of dental prosthesis is usually lengthened by pre-prosthetic phase. For instance, a patient may need to have dental extraction or multiple dental fillings prior to the prosthetic treatment. In such a case, if the patient is put into the waiting list of prosthetic service and has pre-prosthetic treatment only by appointment, the whole course of treatment for this patient would be remarkably lengthened and patients in subsequent queues would also need to wait longer. Thus, we try to reduce the queue for prosthetic service by not to put any patient into the prosthetic service waiting list until the pre-prosthetic treatment has completely been provided to them. This is to allow more service sessions that the patient can use for pre-prosthetic treatment and the problem such as waiting extraction wound to properly heal for weeks would not affect other patients' waiting period. Then, to efficiently clear patients from waiting list of dental prosthetic service, we give specific working hours to this service. Usually the afternoon session is devoted to the prosthetic service together with some other multiple-visit dental interventions. Afternoon sessions in sub-district hospitals are also available for the prosthetic service provision. Extra evening service hours–after regular working hours–and extra service hours on the weekends at our main dental unit are also available as other options for the use of dental prosthetic service ..." (Representative dentist).

- **Allocation of dental prosthetic service users to all dentists:**

  "… Even though this dental unit has a prosthodontic specialist, dental prosthetic service users are not limitedly assigned to that specialist but instead assigned to all dentists here in the dental unit. Then, the role of our specialist is to be the consultant in cases requiring complicated dental prosthetic care. More advanced cases requiring specialized skill to properly deliver the dentures can be referred from other dentists in our dental unit to that specialist as well ..." (Representative dentist).

- **Considerations in selection of dental lab for denture fabrication:**

  "… Since our dental unit is in the Greater Bangkok Metropolitan area which is not far from Bangkok (the national capital city), the selected dental lab is then located there. The most important reason for our selection of such dental lab is the good quality of dental work pieces. In addition, since this dental lab gets its job from several nearby dental clinics and hospitals by its own messenger– with adequate frequency of collection and return of dental work pieces to the this hospital twice a week, then we can reduce cost related to transferring dental work pieces between the lab and our hospital. Waiting duration for return of dental work pieces to hospital is also short …" (Representative dentist).

Apart from the face-to-face interview of the service provider, telephone interview of the service recipients who utilized the service in fiscal year 2010 and 2011 is also conducted to provide additional information regarding patient satisfaction

and quality of service provision as assessed from service recipient's perspective. For this small-sized hospital case, there are 4 service recipients randomly selected for the interview. These recipients comprise 3 cases of complete denture and a case receiving maxillary and mandibular partial dentures with more than 5 replaced teeth. These service recipients utilize the service because it is free of charge. Nonetheless, they are very satisfied with the service.

"… I have no teeth and I wanted to have teeth for chewing. So I went there and dentist said it was free for me. I like my denture and I wear it every day. I can chew but it dislodges easily because there is no tooth left. I went for correction once and I think it is acceptable now …" (Male service recipient with complete denture).

"… I like caring manner of dentist and I did not wait for long to get my teeth done. Dentist gave me date and time of appointment so I didn't have to wait long in front of dental room. He also taught me how to take care of my denture…" (Female service recipient with maxillary and mandibular partial denture–each with > 5 replaced teeth)

Nonetheless, regardless of good satisfaction of service, a case receiving complete denture complains about the problem of unacceptable prosthesis dislodgement during chewing.

"… Even though, I went for other two additional visits for correction, my dentures are not tight. So I wear them only when I go out…" (Male service recipient with complete denture).

5.3.2 Managerial Lessons Learned from Medium-sized Best Practice Unit

Key informants of the medium-sized best practice unit are hospital director and the head dentist of hospital dental unit. Key managerial strategies can be summarized as followed.

Hospital director:

The hospital director has previously attended trainings related to strategies in hospital management and comprehensive improvement in quality of health care leading to hospital accreditation organized by Institute of Development Science. He has initiated several projects related to healthcare quality improvement in this hospital and implementation of these projects has led to the highest level of hospital accreditation. By the time of this interview, the hospital is continuously preparing for the process of re-accreditation. The hospital has also received the claim award from the NHSO, to recognize high quality in report of claim information. He suggests key success factors related to provision of the high-cost dental prosthetic service as followed:

- **Teamwork and good co-operation among working sections as a key to efficiency healthcare service provision:** "… I think that teamwork of personals is a crucial factor leading to success in provision of this service. In addition, good co-operation among sections within hospitals, with sub-district Health Promoting Hospitals, and with local health volunteers add to efficiency in healthcare service delivery. With good communication between our dental unit and hospital financial unit, it brings about accurate making of claims which do not exceed the standard ceiling prices specified by the NHSO.

This consequently results in our success of gaining complete service reimbursement. Co-operation between our dental unit and local health volunteers also facilitates public health relation regarding provision of this service, allows case finding in community, and enables oral screening and case referral from the sub-district hospitals. To promote good relationship among health personals in all sections of this hospital, I provide many activities–such as water color drawing, new year celebration, and others–have been organized to familiarize all personals and allow relaxation. The activities potentially bring about good working condition and promote our performance in achieving routine duties…" (Hospital director).

- **Monitoring of service delivery extent and service reimbursement situation:** "…We have our own committee to monitor delivery extent of all healthcare services and situation of related claims and reimbursement. The committee, called 'Claim Center', comprises representative personnel–one from each hospital section–to undertake the task of service provision and reimbursement situation monitoring. Information related to all healthcare services and our claims and reimbursement is collected throughout the fiscal year and kept as statistics for at least 3 years. Every 6 months, our committee organizes the meeting to review the situation at half year and fiscal year end. Problems related to service under-provision and incomplete service reimbursements are widely discussed. Reasons related to incomplete service reimbursements are further investigated through inquiry to regional office of NHSO. The half year meeting would bring about prompt action to improve the

service in the other half of fiscal year while review closed to fiscal year end allow us to plan for the consecutive fiscal year…" (Hospital director).

- **Specifying roadmap in healthcare service provision:** "…Roadmap is a goal setting strategy applied to all our tasks here in hospital. One part of hospital roadmap lists all tasks needed to be achieved by the dental unit with specified feasible goals. For each task, a person is assigned to be responsible for monitoring achievement of the goal in terms of quantity and quality. This strategy helps reminding us of all tasks needed to be done and allow progressive monitoring over time. Problems related to inability to achieve our goals are also collected and discussed for further development…" (Hospital director).

Representative dentist:

The other important informant is the representative dentist who is also the head of the dental unit. As revealed in the interview, this dental unit has similar strategy of putting service users in the waiting list of dental prosthetic service as that of the small-sized best practice unit. Such strategy is not to put any service users in the waiting list until pre-prosthetic care has completely been provided. Otherwise, they could receive pre-prosthetic service only by appointment which would potentially lengthen the waiting list of prosthetic service. The dental unit used to face the problem of having patients waiting for the service for very long period of 6 months to 1 year. Thus, system of prosthetic service provision has been improved in some ways. The lessons learned from the improvement are summarized as followed.

- **Rescheduling service hours to suit different groups of healthcare beneficiaries:** "… In general, there are three main groups of healthcare beneficiaries comprising beneficiaries of Civil Servant Medical Benefits Scheme (CSMBS), beneficiaries of Social Security Scheme (SSS), and UC beneficiaries. CSMBS beneficiaries who are government officials usually miss the appointment during the day and their free time is usually in the evening or on the weekends. SSS beneficiaries are workers in the private sector. Appointment during the day would cause absence from work and even loss of income among these workers. Thus, these two groups of dental service users are usually recommended and scheduled to receive dental service in the evening extra hours and on the weekends. Then, most of the patients using our service in regular working hours are UC beneficiaries. Such rescheduling of service hours would allow UC beneficiaries (who are eligible users of the high-cost dental prosthetic service) to gain better service access. Our afternoon working hours are also devoted the dental prosthetic service together with other multiple-visit dental interventions to allow better flow of the service users…" (Representative dentist).

- **Oral screening and post-delivery follow-up at sub-district Health Promoting Hospitals:** "… Since we have 4 dentists in our unit while only 3 dental chairs are available. A dentist and oral hygienists are usually rotated to work in the community at the sub-district Health Promoting Hospitals. Then, some steps of the dental prosthetic service are able to be provided in such facility outside the main hospital. By doing this; better case finding, referral to

main hospital for further treatment, and post-delivery follow-up can be improved especially among local residents living far away from our main district hospital…" (Representative dentist).

Service recipients:

Apart from the interview with the providers, 4 service recipients are randomly selected. These interviewed service users comprise a case of maxillary and mandibular partial dentures with less than 5 replaced teeth, two cases of partial dentures with more than 5 replaced teeth in both arches, and a case of complete denture. All service recipients are very satisfied with service in terms of professional care, acceptable duration devoted to total course of treatment, and acceptable waiting time in front of the dental room.

"…My reason for using the service at the hospital was that I did not need to pay and it is close my house. I believe that the quality of work here is not different from that of private dental clinic. I like it here and my dentures work very well without any correction after delivery…" (Female service recipient with complete denture).

Nonetheless, complaints are found among cases with partial dentures. These problems are denture dislodgement and pain on chewing in mandibular prostheses even with an additional dental visit for correction.

"… I have pain and easy dislodgement of my denture. So I wear them only when going out…" (Female service recipient with maxillary and mandibular partial denture–each with > 5 replaced teeth).

5.3.3 Managerial Lessons Learned from Large-sized Best Practice Unit

Key informants of the large-sized best practice unit are hospital director and head of the dental unit. Important issues revealed from the interview are summarized as followed.

Hospital director:

"I have to honestly revealed that the hospital has not gained any plus regarding proportions of hospital income and spending in the last 3 fiscal years. Since this large-sized hospital has a large number of service users together with considerable number of healthcare personals, hospital spending has thus exceeded the total income in these recent years. Nonetheless, for the high-cost dental prosthetic service, gaining of the service reimbursement is quite complete and provision of the service does not contribute to the mentioned problem–which is importantly influenced by services for chronic diseases. Even without the plus in hospital income, I don't assign any limit specified for any of the services provided at this hospital. From my view, patients should be cared first without much concern of losing money at the fiscal year end. If the care is really needed by patient, then it must be provided without much financial concern. I would suggest that public spending should be better allocated to subsidize such monetary loss in hospital operation. Anyway, even with such problem, I don't have any policy to admit more inpatients to get additional money from the NHSO. All claims from this hospital are also honestly made and this holds true to the high-cost dental prosthetic service in which the claim values are well under the standard reimbursement prices. I would suggest that rational use of drugs, honest claim for service reimbursement, and appropriate prescription of care would help the health system to be financially viable in the long-run…" (Hospital director).

Representative dentist:

Several aspects of dental prosthetic care in this hospital are quite similar to the mentioned best practice dental units. Thus, only one distinct strategy is revealed in details here. Unlike other best practice units that have the system of waiting list for the prosthetic service, this dental unit does not have any waiting list regarding the service. "… Dentist who first screens the patient requesting dental prosthetic service is responsible for treatment planning and further appointment for pre-prosthetic service right away. Once oral condition of a certain patient is ready for prosthetic treatment, we promptly provide the service. I suggests that if the first visit is used for screening and putting patient in the waiting list, then this patient is needed to be appointed for another visit to start the course of treatment. Consequently, 2 oral examination sets, 2 times of sterilization, 2 patient's visits to hospital are at least needed. This example simply shows inefficiency in management. If there is something that we can provide right from the first visit, then the unnecessary loss can be avoided…" (Representative dentist).

Service recipients:

For this case study, there are 5 service recipients randomly selected for interview. These recipients comprise 2 cases of partial denture with less than 5 replaced teeth, 1 case of maxillary single denture and mandibular partial denture with more than 5 replaced teeth, and 2 cases of complete denture. Reasons for using the service at this hospital include no need to pay for service, recommendation by another service user, close distance to the hospital, and previous failure of prosthetic care given by private provider.

All of these service users are highly satisfied with the service. “… I think dentist here is very kind and caring. That’s why I really like the service here…” (Female service recipient with maxillary single denture and mandibular partial denture with > 5 replaced teeth)

Almost all service recipients always wear their dentures, except for only a case of complete denture who wear the prostheses only when going out to public. “… I have pain on chewing and I cannot bite food so I don’t wear it at home…” (Female service recipient with complete denture)

CHAPTER VI

DISCUSSIONS AND CONCLUSIONS

Contents in this final chapter of discussions and conclusions are organized into following 5 parts:

- Evidence-based answers to the research questions
- Theoretical implications of the findings
- Implications for practitioners
- Study limitations
- Directions of future research

6.1 Evidence-based Answers to the Research Questions

6.1.1 Relative Technical Efficiency of High-cost Dental Prosthetic Service

The first question in the dissertation requires elucidation of technical efficiency measures in a single production activity of the high-cost dental prosthetic service provision under UC. The firms included in this efficiency analysis are dental units of Thai district hospitals nationwide. Parameters related to such production activity in fiscal year 2010 and 2011 are separately analyzed year-by-year using input-oriented BCC DEA Model.

The results in this study show 3 kinds of efficiency measure: overall technical efficiency measure (TE_i^{CRS}), pure technical efficiency measure (TE_i^{VRS}), and scale efficiency measure (SE_i). The relationship of these 3 measures of efficiency is that overall technical efficiency measure is the product of pure technical efficiency

measure and scale efficiency measure. The relationship can be written in equation form as followed.

$$TE_i^{CRS} = TE_i^{VRS} * SE_i$$

In fiscal year 2010, average values of these 3 measures of efficiency can be summarized as followed:

- Mean $TE_i^{CRS} = 0.58$
- Mean $TE_i^{VRS} = 0.69$
- Mean $SE_i = 0.84$

For the latter fiscal year of 2011, the average values of the 3 measures of efficiency can also be summarized as followed:

- Mean $TE_i^{CRS} = 0.54$
- Mean $TE_i^{VRS} = 0.65$
- Mean $SE_i = 0.87$

Since the efficiency analysis in this context is an input-oriented analysis, thus the aim of this analysis is to explain that, if service delivery extent would be kept at the same level–maintaining amount of all service outputs, how much consumption of all service production inputs (labor and operating expenses) could be minimized. The analysis also assume variable returns to scale assumption–meaning that amount of outputs is not assumed to be directly proportionate to amount of inputs, which is relevant to the real phenomenon of healthcare service production. Then, out of the 3 measures of efficiency, the value that directly contains answer to the research question is the average value of pure technical efficiency (mean TE_i^{VRS}).

In fiscal year 2010, the mean TE_i^{VRS} equals 0.69. This can be interpreted as that the average percentage of pure technical efficiency in provision of the high-cost

dental prosthetic service among analyzed firms in fiscal year 2010 is around 69%. Thus, there is still up to 31% on average of pure technical inefficiency which could be eliminated. In other words, all analyzed firms in fiscal year 2010 could averagely reduce their consumption of production inputs by 31% while maintaining the same level of service production outputs. This is the answer for the first research question from the information of fiscal year 2010.

For fiscal year 2011, the mean TE_i^{VRS} equals 0.65. This is interpreted as that the average percentage of pure technical efficiency in provision of the high-cost dental service among analyzed firms in fiscal year 2011 is around 65%. Thus, there is still up to 35% on average of pure technical inefficiency which could be eliminated. In other words, all analyzed firms in fiscal year 2010 could averagely reduce their consumption of all production inputs by 35% while maintaining the same level of service production outputs. This is the answer for the first research question from the information of fiscal year 2011.

In comparison of these two fiscal years, the results show slight decrease in pure technical efficiency on average in the latter fiscal year of 2011. This means that inefficiency in use of service production resource inputs (labor and operating expenses) has been averagely increased. In other words, efficiency in use of service production inputs has been averagely decreased.

Taking the relationship of the efficiency measures into account, the empirical results regarding these measures in this study can thus imply the following important messages:

- A direction to improve overall technical efficiency in provision of the service, as suggested by finding of pure technical inefficiency, is by means of optimizing (minimizing) the use of resource inputs consumed by local providers to produce such service.
- Finding of scale inefficiency implies that there is still possibility to improve efficiency in delivery of this high-cost dental prosthetic service. When provision of this dental service becomes more efficient especially with condition that is more competitive or having better or perfect market competition. Then the firms can improve their efficiency regarding provision of this service close to the technical efficiency under constant returns to scale assumption.
- Optimal allocation of dentists should be considered as suggested by the finding of average pure technical efficiency which does not necessarily increase with growing number of labor inputs.
- Decrease in technical efficiency measure in the later fiscal year could be due to more number dentists entering the whole system, more reimbursement of the service, and the extensive flooding Thailand in 2011 while the output growth did not considerably increased.

To additionally explain about exploitation of scale economy just mentioned in the last key message, an example can be given by consideration of the selected best practice dental unit in the South in the qualitative phase of this study. This dental unit has up to 4 dentists while having only 3 dental chairs at its dental room. Thus, there is an excess in number of dentists compared to that of dental chair. This dental unit

gains its pure technical efficiency score of 1.00 in both fiscal years, implying that it operation regarding this service is technically efficient under VRS assumption. In other words, it is a technically efficient firm. Nonetheless, this firm does not gain scale efficiency score of 1.00, implying that scale inefficiency exists and the firm can improve its service productivity even the firm is already the technically efficient firm. Therefore, if this firm could adjust its scale of operation concerning this service; for example, by means of getting an additional dental chair; all 4 dentists would consequently work at the same time and excess in number of dentists would no longer exist. Then, this dental unit could improve its service productivity, or its ratio between an output index (which accounts for all service outputs) and number of dentists, by means of adjustment in its scale of operation.

Above all, care should be taken not to misinterpret hospitals with low efficiency scores as being inefficient in overall dental service delivery. This is due to the fact that only one dental intervention from a broad scope of dental services is taken into account here.

6.1.2 Factors Related to Pure Technical Efficiency

The second research question requires elucidation of factors related to the previously identified pure technical efficiency measures. The model used to identify such relationship is Tobit regression model. Three interested explanatory variables comprise hospital size, number of affiliated dentists, and locations of firms in the central region compared to other locations in all other regions combined. The outcome variable is the pure technical efficiency score.

The empirical results have shown that these 3 explanatory factors are highly, statistically associated with the efficiency measure. Hospital size and location of firms in the central region of the nation are positively related to better pure technical efficiency in provision of the high-cost dental prosthetic service. In contrast, growing numbers of affiliated dentists are negatively associated with the pure technical efficiency. Nonetheless, values of beta coefficients found for all the 3 explanatory variables are relatively small, implying low contribution of these explanatory variables in predicting the outcome variable.

Although it is well aware that different hospital sizes indicated by inpatient bed numbers in the context of Thailand should be viewed only as rough categorization of district hospitals by size and should be simply used as categorical variable, some problematic issues would arise from doing this as followed.

- Firstly, if this variable is to be used as a dummy variable in the Tobit model, a primary problem then arises from the need of grouping hospital sizes into categories for further coding assignment. A possible way of grouping is do the same as that used for descriptive statistics part: small-sized (10-30 beds), medium-sized (60 beds), and large-sized (90 or more beds) hospitals. Nonetheless, interpretation of result would be again problematic since clear cutting in characteristics of these groups could awkwardly be stated.
- Secondly, regarding the code assignment for dummy variable, another problem arises from the need to decide which category to be coded as reference category.
- Thirdly, since efficiency analysis regarding dental service provided in all sizes of Thai district hospitals, to the best of author knowledge, has not previously

been conducted, there is a lack of evidence in the context of Thai public dental service to rationally exemplify any means of categorization.

- Fourthly, it has been suggested from literature specific to the context of Thailand that specification of hospital sizes by inpatient bed numbers is consistent with information identified by geographic information system or GIS (MOPH, 2006: Online), so it is presumed by author that larger hospital sizes would be related to higher population density and less degree of local hardship which could positively influence efficiency in service provision. This presumption is also consistent with the evidence that district hospitals listed in the rural and very rural areas are only those of small-sized (MOPH, 2009: official correspondence)

According to these considerations, instead of using this variable as dummy ones, this pioneering study provides evidence for such issue by avoiding imposition of groups to the variable and freely run this variable by its numbers of inpatient beds. This is to explore the trend between this factor and the efficiency scores, instead of identifying relative magnitudes of relationship across imposed size categories. As shown by the result, this approach reveals positive relationship between the growing sizes of hospitals and the efficiency scores. This may be due to the fact that larger hospitals are more likely to be situated in larger districts while those situated in rural and very rural areas are smaller district hospitals (MOPH, 2009: official correspondence). Niggebrugge and colleagues also suggested that multiple deprivations in rural area could result in poorer access to care, dearth of health personnel, and limited availability of facility–such as roads and post office (Niggebrugge et al., 2005: 2743-2753). These proposed underlying factors might influence the efficiency in this

context as well. Thus, further investigation of these factors should add to understanding of influencing factors related to provision of this dental service.

Location of dental unit in the central region of the nation can be advantageous in that it is closer to the national capital (Bangkok) where most of the dental laboratories in the nation are situated. As exemplified in the qualitative phase of this study, two of the selected best practice units are situated in the central region. The dental unit which is situated in the Greater Bangkok Metropolitan area gains the benefit of close distance to its dental lab in Bangkok by getting messenger from lab to collect and return the dental work pieces twice a week for free. The other dental unit can also use cheap van service for its communication with dental lab in Bangkok for once a week. From this example, short duration of waiting time for the dental work pieces to be returned to hospital and lower logistic cost for transferring the work pieces could improve efficiency in service provision.

Growing numbers of affiliated dentist are found to be negatively related to the efficiency measures. This may seem contradictory to intuition. One study also found contrastive result from this finding. Lipscomb and Douglass conducted a classic, activity-based, production function analysis of dental service production to provide answer to whether larger dental practices defined by more numbers of dentists were more efficient. In their study, technical and cost efficiencies were improved with increased sizes of dental practice, from 1 to 4 inputs of dentists. Nevertheless, due to limitation in data, the study failed to further illustrate whether the efficiencies progressively related to inputs of 5 or more dentists. (Lipscomb and Douglass, 1986: 635-661) In contrary to that study, empirical result in this study instead shows negative relationship. Such negative association may be alternatively explained by an

economic law of diminishing marginal returns. This economic law can be explained as that when a production factor is added more and more to production process, while all other production factors remain unchanged, this will at some stage produce lower marginal product (Samuelson and Nordhaus, 2001). In other words, once the input number of dentists has exceeded the optimal number, there would be too many dentists for the service burden and this would further result in lower efficiency.

6.1.3 Lessons Learned from the Best Practice Units

The third research question requires explication of managerial lessons learned from the best practice dental units. To provide such explication, 3 best practice dental units with different sizes are selected for further investigation by means of qualitative study method. Key managerial strategies in achieving efficient provision of the high-cost dental prosthetic service suggested by these best practice units are summarized as followed.

- Dental prosthetic service users should be distributed to all affiliated dentists instead of being limitedly appointed to certain dentist, especially a prosthodontic specialist.
- Setting specific working hours devoted to the dental prosthetic service is a strategy to enhance patient flow and to reduce number of patients waiting for the service in the list.
- Scheduling service hours to suit different groups of service users with different kinds of insurance or health benefits can allow dental patients to gain access to dental care at their best available time, avoid causing problem of patient’s work absence, avoid failing to keep dental appointment, and provide

better access to the high-cost dental prosthetic service among eligible UC beneficiaries.

- Periodic assessment of the dental prosthetic service delivery extent is recommended to inform the dental unit whether the service has been adequately provided.
- Decentralization of the high-cost dental prosthetic service provision to sub-district Health Promoting Hospitals can allow better access to care among local residents who live far away from the main district hospital. The decentralization of the service also helps reducing influx of patients to the main district hospitals. Some steps of the service; such as the first visit of oral screening and treatment planning, post-delivery care, and minor correction of dentures; can also be undertaken at the sub-district facility.
- Teamwork and good co-operation among different working sections can improve efficiency in provision of the dental prosthetic service. Good co-operation between hospital dental unit and financial unit would allow better preparation of evidences for claim and success in gaining complete service reimbursement. Co-operation between dental units and local health volunteers can ease finding of individuals in need of dental prosthetic service in local community. Co-operation between the main hospital dental unit and sub-district dental unit would ease effective case referral or allocation of some steps to be undertaken in the sub-district facility.
- Selection of dental lab for denture fabrication can influence quality of dental work pieces, waiting time for return of dental work pieces back to the hospital,

and logistic cost related to transferring dental work pieces back and forth between hospital and dental lab.

Above all, application of these lessons learned to a certain dental unit should be considered whether it is feasible and appropriate for specific context of each district hospital.

6.2 Theoretical Implications

(A) Contribution as a Pioneering Study

This dissertation has contributed to the theory of efficiency in operation of not-for-profit oral healthcare provider. Firstly, this thesis is a pioneering study which applies DEA technique to analyze efficiency of public dental service in the context of a developing country in Asia. As previously shown in Chapter III, section 3.3; former studies applying the DEA technique to analyze efficiency in public dental service have been undertaken limitedly in the context of developed countries–such as England and Finland. Unlike the well-established public dental service in the developed countries–where numbers of dental professionals and oral healthcare funding are more adequate, efficiency analysis of public dental service in the context of developing country–where those oral health resources are scarce–would provide extremely valuable guide in optimizing these scare resources to yield the best possible service productivity.

Secondly, based on the potential use of DEA technique for activity-base analysis, this study is unique in applying the efficiency analysis technique as a fair evaluation tool to assess post-implementation outcome of a public dental program

which requires considerable public spending and affect a large number of patients throughout the country. A former study which has applied DEA technique for activity-based analysis was undertaken by Coppola and colleagues in 2003 to evaluated provider performance in provision of posterior dental restorations (Coppola, et al., 2003: 445-456).

Thirdly, to the best knowledge of the author, this study is the first efficiency analysis in the public provision of dental prosthetic service which is the most expensive category of routine dental service provided at the district hospital level in Thailand.

(B) DEA as an Applicable Evaluation Tool for Thai Public Dental Service

This dissertation has contributed to provide evidences for consideration of whether DEA technique can be used as an applicable evaluation tool to assess post-implementation of public dental program in the context of Thailand. Findings in this study evidently support such proposition the DEA can be an assessment tool of choice to evaluate public dental service in the context. Evidences supporting this notion can be summarized as followed.

a) Application of DEA technique with VRS assumption (BCC DEA model) can be applied to the context of Thai dental system of analysis, since characteristics of the dental system are consistent with the previously mentioned exceptional characteristics of healthcare system causing market failure and compromised price mechanism–see Chapter II, section 2.4(B). Evidences in this thesis showing these exceptional characteristics include unpredictable demand for service–larger hospitals do not necessarily get more number of service recipients, hiring of excessive number

of dentists compared to available facility–such as dental chairs–which causes scale inefficiency, considerable degree of technical and scale inefficiency identified, inequality in service availability to local residents across different firms of analysis, and others.

b) Unlike other criteria-based performance assessment approaches, DEA adopts relative concept in performance measurement–avoiding imposition of assessment criteria that may not be applicable to the different contexts of local dental providers. DEA instead uses peer comparison approach to identify benchmark from the real practice and to compare inefficient firms to appropriate benchmark with feasible goal setting.

c) In contrast to some criteria-based performance assessment approaches which target only service outputs, DEA allows consideration for optimizing service inputs as well which makes it a very useful tool for detection of health resource overuse and goal setting for minimizing consumption of resource inputs.

d) DEA is flexible in that different perspectives can be analyzed and different choices of data can be used to reveal different aspects of efficiency. In this dissertation, payer's perspective with the use of reimbursement value as one of the service production inputs reveal efficiency of non-profit organization firms viewed by buyer of their service products given constraint of limited budget availability. Alternatively, the DEA can be applied to payer's perspective but with the use of claim value to reveal firms' real behavior in claim for reimbursement. Another application can be from providers' perspective with the use of real cost data, which needs more complicated cost identification method, to reveal efficiency in real service production. Nonetheless, this lastly suggested approach may not be as useful for budgetary

planning compared to the payer's perspective and reimbursement which results in opportunity loss may not be well revealed.

e) Not only the national or regional view on efficiency in production of the service can be yielded by the use of DEA, individual firm score can also be used to focus on efficiency improvement of a certain individual firm as well.

(C) Better Quality of Care with Less Cost

Since DEA can guide minimization in consumption of health resource use as well as maximization of output to be yielded from a certain amount of limited health resource, the issue of better healthcare service production with less cost can be feasibly considered. Nonetheless, DEA–which is a quantitative method of analysis–is limited in its ability to reveal qualitative dimension of care. Thus, incorporating both approaches of DEA and qualitative investigation as set example by this dissertation can be further adopted as dual approach to promote better quality of care with less cost.

Direk Patmasiriwat has previously recommended such approach from his quantitative efficiency analysis using DEA. He suggested that efficiency analysis importantly reveals that different firms have different practical limitation as revealed by different efficiency scores. So the main goal setting from quantitative approach should be set only to improve efficiency in healthcare service provision and not to expect 100% efficiency due to the mentioned practical limitation specific to different contexts of local providers. Then both favorable and unfavorable results from DEA can be used to further guide qualitative investigation. Generating lessons learned from best practice units is the constructive use for favorable results while understanding of

local practical limitations among inefficient firms can also be very constructive in guiding appropriate and unique support to these inefficiency entities. Some unique challenges; such as location in island area, large serviced areas with scatter of local villages, far distance from these villages to main local hospital; would influence inefficiency found among these local providers which should not be blamed. (Direk Patmasiriwat, 2007: 96-126)

From the context of analysis in this dissertation, author further address additional issues regarding provision of the high-cost dental prosthetic service. From the finding of inability to provide the service especially in the southern-most provinces with the problem of political unrest, attention is crucially called for these providers. Since the service requires multiple visits to hospital, this would add challenge among local residents in need of the service. Another issue is that the locations of dental labs for denture fabrication are not well distributed, mostly situated in the national capital and major provinces. Thus, those local hospitals with their locations far away from the dental labs would face additional logistic cost of transferring dental work pieces back and forth. Then, setting of the same standard price for reimbursement may not be a suitable strategy and petition for addition reimbursement value should be allow to better support these local dental providers. Improvement in quality of life after service reception is the other important issue to be considered. It is recommended that, apart from telephone interview method used to interview the patients, co-operation of local health volunteers residing in local community could help reveal this qualitative dimension of care.

6.3 Implications for Practitioners

Although implications for practitioners from this dissertation may not be as great as compared to those theoretical implications, due to the fact that this activity-based analytical study is a pioneering study of this field in Thailand, some important recommendations are made here.

(A) Ministry of Public Health

The recommendation here can be specific to consideration by Office of Permanent Secretary of MOPH which is directly responsible for organizing healthcare service in Thailand. This approach of performance measurement can be used to objectively evaluate relative technical efficiency of dental units at district hospital level in providing high-cost dental prosthetic service. The approach is also useful in that it allows utilization of routine dental information to evaluate relative performance of dental units in delivering a certain dental service. Thus, it is recommended that DEA should be considered as an approach of choice in addition to currently used criteria-based performance assessment approaches.

The other important contribution of the MOPH is to further investigate the underlying reasons of some hospitals which are currently unable to provide the dental prosthetic service and support accordingly without attempt to blame.

(B) Individual Dental Unit

Technical efficiency score of a certain dental unit would primarily indicate its performance in dental prosthetic service delivery in comparison with other included dental units providing the same dental service. Areas of inefficiency in production of the service can also be addressed for each dental unit. Consequently, specific

suggestion for each dental unit to improve its efficiency in delivery of the service can be provided.

Lessons learned from best practice units are also recommended to be selectively applied to improve efficiency in provision of the service. Nonetheless, application of the recommended strategies is in need of consideration of whether the strategies are feasible and applicable to the local context of the providers.

As reflected from the service recipients, some post-delivery problems related to denture wearing still exist. Good post-operative instruction especially patients' limitation in chewing and biting, experience of pain and other adverse events which can occur should be warned. Long-term follow-up to assess quality of work is also recommended.

(C) National Dental Funds

One of the missions of the newly established National Dental Funds is to estimate specific budget for the high-cost dental prosthetic service. Information related extent of service delivery to the real service provision at fiscal year-end in both years of analysis would provide baseline information for such purpose. For the purpose of budgetary control, this approach of efficiency analysis would allow detection of excessive use of service production inputs. So the underlying reasons related to such overuse of resource can be further investigated without attempt to blame and local providers of the service can be supported accordingly.

(D) Bureau of Claim Administration, NHSO

Major contribution of the Bureau of Claim Administration is the payer for this program. To further improve financial situation of the funding and avoid financial

viability risk of the program, long-term performance measurement regarding this service using approach illustrated in this dissertation is recommended.

For short-run improvement, quality of data recorded in E-claim database is needed to be considered. Moreover, collection of not only reimbursement values but also claim values would allow better view on both aspects of efficiency in service production given constraint of limited budget and hospitals' behavior in claiming for service reimbursement, respectively.

For long-run contribution, continuous data collection would make availability of panel data which can further be analyzed to further assess technical change over time and related improvement in service productivity. Application of this approach to other healthcare service should also be considered and this would result in improvement in budgetary control regarding global budgeting system if possible.

Petition for additional reimbursement regarding this service should be allowed on case-by-case basis. As previously mentioned, some local providers situated in hardship areas may need additional monetary support to cope with the additional cost of service production due to local limitations, such as location on islands.

6.4 Study Limitations

In addition to the preliminary limitations listed in Chapter I, study limitations are additionally explained here after research has been conducted.

1) Due to limitation in ability of DEA technique to reveal qualitative dimension of health care, qualitative study seem to be mandatory for further investigation of improvement in service recipients' quality of life after care has been provided.

2) Since this dissertation is an activity-based analysis of efficiency in production of the high-cost dental prosthetic service, care should be taken not to misinterpret that inefficient firms are inefficient in overall provision of dental services provided at district hospitals. Best practice dental units regarding this service can be compromised regarding other dental services which have not yet been investigated.

3) Also due to the activity-based characteristic of this study, suggestion regarding exploitation of scale economy is kept limited only to theoretical suggestion, rather than practical suggestion.

4) Due to limitation in available data, only limited number of explanatory factors is analyzed in Tobit regression model.

6.5 Directions of Future Research

Directions of future research are summarized as followed.

1) There are still some of the local dental units which are unable to provide the high-cost dental prosthetic service. Thus, further investigation to reveal underlying reasons by qualitative method would be very useful to identify problems specific to local context of these providers and appropriate support can be provided accordingly to enable provision of the service to local resident.

2) Efficiency analysis that takes all items of dental services provided at the district hospital level into account would be very useful in comprehensive evaluation local dental units' performance in total service productivity.

3) Additional number of explanatory variables should be used to better reveal the relationship between local factors with efficiency scores. Some additional factors can be extent of serviced areas, distance from local villages to main district hospital,

professional preference and experience in service provision, locations in challenging areas–such as islands, and others.

4) To reveal more lessons learned from best practice units, more number of the efficient dental units can be selected for further qualitative investigation.

5) Claim data can be used instead of reimbursement value to additionally reveal firms' behavior in claim for service reimbursement regarding provision of this service.

6) More comprehensive performance measurement which additionally takes all dental services provided at district hospital into account would be very useful for holistic assessment. Additional dimensions such as preventive and promotive oral healthcare can also be incorporated in the analysis. Better practical guide to exploitation of scale economy can be obtained from doing this as well.

7) Qualitative research which considers local network such as home visit by local health volunteers can be useful in assessment of quality of care after the service has been completely provided at the dental clinic.

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Appendix

Appendix

Qualitative Interview Guidelines

Part 1: Questions for hospital director

1) In your opinion, in terms of quantity or extent of service delivery, do you think that your hospital dental unit has sufficiently provided high-cost dental prosthetic service to service recipients?
2) Is there any positive or negative effect or impact of high-cost dental prosthetic service provision on management of hospital budget? If yes, in which way? Please kindly explain.
3) In your opinion, in terms of quality of work, do you think your hospital dental unit has provided good quality of dental care, especially the dental prostheses?
4) In your opinion, what do you find as strength and weakness of you hospital dental unit in provision of dental service, especially the dental prosthetic service?
5) Is there any problems regarding provision of the dental prosthetic service that your hospital has experienced?
6) What would you like to suggest for further development of this service?

Part 2: Questions for representative dentist

1) In your opinion, in terms of quantity or extent of service delivery, do you think that your hospital dental unit has sufficiently provided high-cost dental prosthetic service to service recipients?

2) Is there any positive or negative effect of high-cost dental prosthetic service provision on management of budget? In which way? Please kindly explain.
3) In terms of quality of work, do you think your dental unit has provided good quality of dental care, especially the dental prostheses? Is there any measure for quality control?
4) What do you find as strength and weakness of you dental unit in provision of dental service, especially the dental prosthetic service?
5) Is there any problems regarding provision of the dental prosthetic service that your dental unit has experienced?
6) What would you like to suggest for further development of this service?

Part 3: Questions for service recipients

1) Why do you choose to receive this service from this hospital?
2) Have you conveniently received the service? If not, please kindly explain.
3) How long do you need to wait from first screening to the first visit of denture fabrication?
4) Are you satisfied with the high-cost dental prosthetic service provided at your hospital?
5) After denture delivery, have you ever been appointed for further follow-up?
6) Have you ever returned to hospital for denture correction? If yes, please kindly explain the reason.
7) Do you usually wear your denture? If not, please kindly explain the reason.
8) Are you satisfied with the professional care?
9) Are you satisfied with the overall service by this dental unit?

VITAE

Name: Chanapong Rojanaworarit
Address: 14/1 Rojanaphan House, Khumueang Road, Ban-Nue District, Mueang, Kanchanaburi Province, Thailand, 71000
Tel: 66-34512256
E-mail: chanapong007@hotmail.com

Date of Birth: October 13, 1980

Education:

Year	Degree	Subject of Study	Name and Location of Study
2001-2006	LL.B.	Law	Sukhothai Thammathirat Open University, Nonthaburi Province, Thailand
2006-2008	B.A.	Information Science	Sukhothai Thammathirat Open University, Nonthaburi Province, Thailand
2001-2008	D.D.S.	Dentistry	Prince of Songkla University Songkhla Province, Thailand
2008-2009	M.P.H.	Public Health (Health System Development)	Chulalongkorn University, Bangkok, Thailand

Professional experience:

2008-present General dental practitioner, private practice, Bangkok, Thailand