การประมาณฟังก์ชันต้นทุนและต้นทุนต่อหน่วย
ของโรงพยาบาลภาครัฐในประเทศไทย

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ESTIMATING THE COST FUNCTION AND UNIT COSTS OF PUBLIC HOSPITALS IN THAILAND

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A Thesis Submitted in Partial Fulfilment of the Requirements
for the Degree of Master of Science Program in Health Economics
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Field of Study	**Health Economics**
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ฮิเดกิ ฮิกาชิ: การประมาณฟังก์ชันต้นทุนและต้นทุนต่อหน่วยของโรงพยาบาลภาครัฐในประเทศไทย. (ESTIMATING THE COST FUNCTION AND UNIT COSTS OF PUBLIC HOSPITALS IN THAILAND) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. อิศรา ศานติศาสน์, 146 หน้า.

ค่าใช้จ่ายด้านสาธาณสุขในประเทศไทยเพิ่มขึ้นอย่างต่อเนื่องเป็นเวลามากกว่าสิบปี โดยเฉพาะการใช้จ่ายของภาครัฐที่มีแนวโน้มเพิ่มขึ้นอย่างเด่นชัดเป็นพิเศษหลังจากที่มีโครงการประกันสุขภาพทั่วหน้าซึ่งส่งผลโดยตรงต่อค่าใช้จ่ายรวมสาธารณสุขที่เพิ่มขึ้น นอกจากนี้ยังพบอีกว่าโรงพยาบาลมีการใช้จ่ายงบประมาณทางด้านบุคลากรสาธารณสุขมากที่สุด คิดเป็นสัดส่วนมากกว่า 60% ของค่าใช้จ่ายรวมทั้งหมดทางด้านสาธารณสุข และเป็นปัจจัยสำคัญที่มีผลอย่างมากที่ทำให้ค่าใช้จ่ายหรือต้นทุนรวมทางด้านสาธารณสุขมีค่าสูงขึ้น

เนื่องมาจากความไม่สะดวกในการเก็บรวบรวมข้อมูลจากโรงพยาบาลเอกชน การศึกษาในครั้งนี้จึงเน้นการวิเคราะห์โครงสร้างต้นทุนและรูปแบบของโรงพยาบาลในประเทศไทย การศึกษาแบ่งเป็น 2 ส่วน ส่วนแรกเป็นการประมาณฟังก์ชันต้นทุนของโรงพยาบาลจากข้อมูลของโรงพยาบาลชุมชนและโรงพยาบาลจังหวัดรวมทั้งหมด 704 แห่งในปี พ.ศ. 2549 ส่วนที่สองเป็นการพัฒนาแบบจำลองทางเศรษฐมิติเพื่อใช้ในการประมาณค่าต้นทุนต่อหน่วยในการให้บริการของโรงพยาบาลจากข้อมูลของโรงพยาบาลจำนวน 23 แห่งระหว่างปี พ.ศ. 2541 ถึง พ.ศ. 2546

ฟังก์ชันทรานส์ลอกถูกนำมาใช้เพื่อการประมาณค่ารูปแบบของต้นทุนที่เกิดขึ้น ผลลัพธ์ที่ได้แสดงถึงรูปแบบของต้นทุนระยะสั้นมากกว่าระยะยาว ปัจจัยหลักของต้นทุนในการดำเนินงานโรงพยาบาลได้แก่การให้บริการรักษาผู้ป่วยในและราคาปัจจัยการผลิตต่าง ๆ ยกเว้นแพทย์ จำนวนผู้ป่วยนอกที่มีการใช้ประกันสุขภาพทั่วหน้าเป็นอีกปัจจัยที่ส่งผลต่อระดับต้นทุนของโรงพยาบาลที่เพิ่มสูงขึ้น จากการประมาณค่าพารามิเตอร์สำหรับการหาค่าต้นทุนพบว่าการไม่ประหยัดต่อขนาดของทั้งโรงพยาบาลชุมชนและโรงพยาบาลจังหวัดควรแก้ไขโดยการลดขนาดของโรงพยาบาลให้เล็กลง การประหยัดต่อขอบเขตการให้บริการระหว่างการให้บริการผู้ป่วยนอกและผู้ป่วยในชี้ว่าคลินิกผู้ป่วยนอกที่มีการดำเนินงานแยกออกมาต่างหากอาจมีผลให้ต้นทุนต่อหน่วยสูงขึ้น ดังนั้นการกำหนดขนาดที่เหมาะสมและการให้บริการที่ผสมผสานของโรงพยาบาลจึงเป็นสิ่งที่เหมาะสมเพื่อป้องกันปัญหาที่อาจเกิดขึ้นดังกล่าว

แบบจำลองเศรษฐมิติได้ถูกพัฒนาขึ้นเพื่อประมาณค่าอัตราส่วนต้นทุนต่อหน่วยระหว่างการให้บริการผู้ป่วยนอกและผู้ป่วยในเพื่อสามารถประมาณค่าของต้นทุนต่อหน่วยจากต้นทุนทั้งหมด แบบจำลองต้นทุนต่อหน่วยแสดงค่าอัตราส่วนต้นทุนต่อหน่วยระหว่างคนไข้นอกและคนไข้ในเฉลี่ยที่ 1:13 สำหรับโรงพยาบาลชุมชนและ 1:28 สำหรับโรงพยาบาลจังหวัด ขณะที่ค่าประมาณในการดำเนินงานโดยทั่วไปที่มีการศึกษาก่อนหน้านี้และถูกใช้ในกระทรวงสาธารณสุขอยู่ที่ 1:14 และได้มีการเปลี่ยนแปลงค่าที่แตกต่างไปจากเดิมเป็น 1:18 ในระยะหลัง อย่างไรก็ตามเพื่อความถูกต้องแม่นยำของตัวเลขอัตราส่วนจึงควรมีการศึกษาครั้งต่อไป

สาขาวิชา เศรษฐศาสตร์สาธารณสุข ลายมือชื่อนิสิต ....

ปีการศึกษา 2550 ลายมือชื่ออาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก ....

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KEYWORD: HOSPITAL COSTS / UNIT COSTS / TRANSLOG / THAILAND

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Health expenditure in Thailand has escalated over the past decades. This trend has been prominent in the public spending, where its proportion over total health expenditure (THE) has been increasing particularly after the implementation of the universal coverage (UC) scheme. Hospitals consume the highest proportion of health resources, which exceeds 60% of total health spending, and so have been playing a significant role in the escalation of THE.

Due to difficulties in obtaining data from private hospitals, this study aims to analyse the cost structure and characteristics of public hospitals in Thailand. The first component estimated the hospital cost function using 704 community and provincial hospitals in 2006. The second component developed an econometric model to estimate the unit costs of hospital services by obtaining 23 sample data from past studies between 1998–2003.

Translog function was assumed for the estimation of the cost function. The results favoured the short-run cost function over the long-run. The major determinants of hospital costs included inpatient services and input prices, except for medical doctors. The proportion of UC outpatients was identified to shift-up the cost level of hospitals. UC seems to be one of the cost escalation factors of hospitals. From the estimated cost function parameters, diseconomies of scale for both community and provincial hospitals were identified which suggest the down-sizing of hospitals. Partial economies of scope between outpatient and inpatient services was identified suggesting that a stand-alone outpatient clinic would result in an increased unit cost. The opposing effects of scale and scope economies meant that the optimum size and service mix of hospitals should be identified by striking the balance between these two factors.

The econometric model developed to estimate the unit cost ratio between outpatient and inpatient services enables the estimation of unit costs from full costs. Unit cost simulations revealed an average ratio between outpatient and inpatient unit costs of 1:13 for community hospitals, and 1:28 for provincial hospitals. Whilst the former approximates the current practice of 1:14 used by the Ministry of Public Health, the latter deviates significantly from the current practice of 1:18. Further studies are required to confirm the accuracy of the ratio.

Field of Study: HEALTH ECONOMICS Student's Signature: ....

Academic Year: 2007 Principal Advisor's Signature: ....

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
AIDS	Acquired Immunodeficiency Syndrome
CHOICE	Choosing Interventions that are Cost-Effective
CSMBS	Civil Servants Medical Benefit Scheme
DALY	Disability-adjusted Life Years
DRG	Diagnosis Related Group
GDP	Gross Domestic Product
GGE	General Government Expenditure
GLS	Generalised Least Squares
HIV	Human Immunodeficiency Virus
ICDA	International Classification of Diseases, Adapted (for USA)
JGLS	Joint Generalised Least Squares
MMR	Maternal Mortality Ratio
MOPH	Ministry of Public Health (Thailand)
NPS	Non-patient Services
NRPCC	Non-revenue Producing Cost Centre
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PHC	Primary Health Care
PS	Patient Services
RPCC	Revenue Producing Cost Centre
RW	Relative Weight
SC	Schwarz Criterion
SSS	Social Security Scheme
SUR	Seemingly Unrelated Regressions
THB	Thai Baht
THE	Total Health Expenditure
Translog	Transcendental Logarithm
TMCF	Translog Multi-product Cost Function
UC	Universal Coverage
USA	United States of America
USD	United States Dollar
WCC	Weak Cost Complementarities
WHO	World Health Organization

CHAPTER I

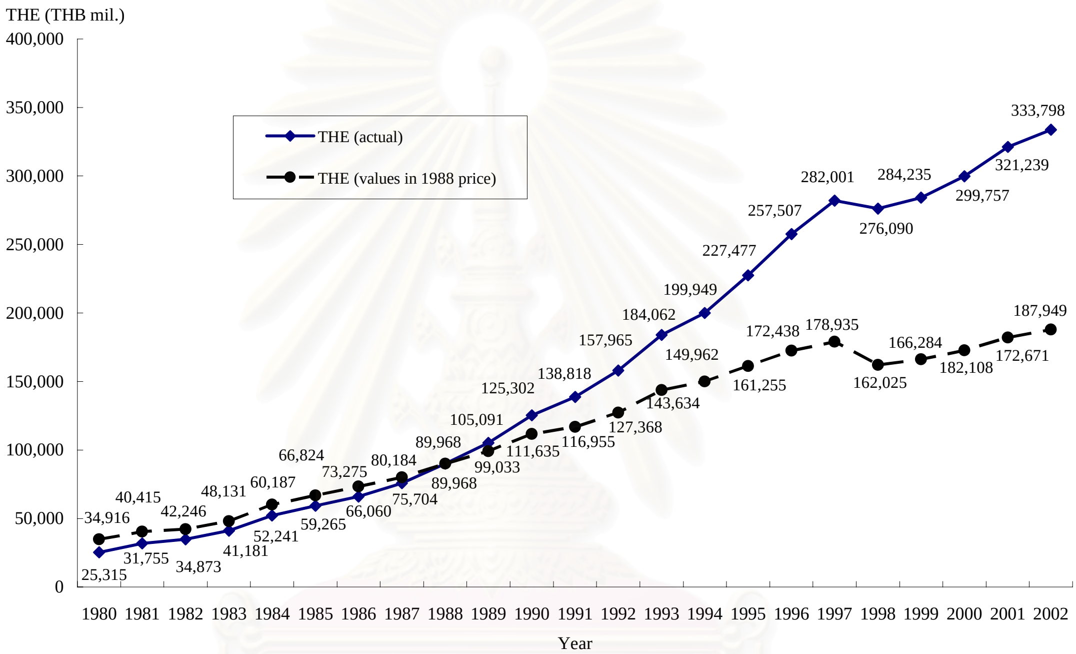
INTRODUCTION

1.1 Background of the study

The escalation of health expenditure has been a universal phenomenon over the past decades. Whilst its degree has been significant in high-income countries, low and middle-income countries have similarly experienced such trends. Many factors may have affected the escalation of health expenditure such as the evolving high-cost medical technologies, changes in disease patterns, or increasing demand for health care services. Amongst the various kinds of services provided in the health sector, hospitals absorb the lion's share of health system resources. The proportion of hospital consumptions typically ranges between 50−80% of the government recurrent health expenditure (Barnum & Kutzin 1993). Hospitals also utilise large portions of the most highly trained health professionals (Newbrander *et al*. 1992).

Thailand is of no exception of such characteristics. Figure 1-1 illustrates the health expenditure trend in Thailand between 1980 and 2002. The total health expenditure (THE) has risen approx. 13-fold between 1980 and 2002 in nominal term (THB 25,315 million to THB 333,798 million) or about five-fold in real term (THB 34,916 million to THB 187,949 million, as of 1988 value). Whilst the health expenditure escalation was temporarily suspended during the economic upheaval faced after the 1997 financial crisis, it has found its way back for a continuous rise soon after. Table 1-1 presents the characteristics of health related expenditure in Thailand over the recent ten years which has been estimated in the national health account. Amongst various potential causes for the health expenditure escalation, hospitals have played significant roles which accounted for 63.5% of THE in 2002. The proportion of general government expenditure (GGE) on health has been relatively stable. However, the public proportion of THE has increased continuously over the recent ten years. This trend has particularly been prominent after the implementation of universal coverage scheme (UC) where the proportion of government health expenditure over THE has risen from 56.4% to 63.9% between 2001and 2005.

Figure 1-1: Total health expenditure in Thailand, 1980−2002



Source: MOPH 2005

Table 1-1: Composition of health expenditure in Thailand, 1996–2005

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
General government expenditure on health as % of GGE	10.31	10.03	8.48	7.29	9.97	9.03	9.27	11.87	11.17	10.87
General government expenditure on health as % of THE	47.18	53.95	54.82	54.89	56.15	56.38	63.47	63.67	64.69	63.94
Private sector expenditure on health as % of THE	52.82	46.05	45.18	45.11	43.85	43.62	36.53	36.33	35.31	36.06
Total expenditure on hospitals as % of THE	59.79	56.24	55.05	63.26	62.79	64.51	63.51	n/a	n/a	n/a

Source: WHO 2007

The implementation of UC seems to have brought an uprise in demand for health care services. The capitation and diagnosis related group (DRG) based payment mechanisms, which were employed by UC in expectation to contain the escalation of health care expenditure, do not seem to have been successful. In combination of the difficulties in demand containment and capitation based revenues of hospitals, many public hospitals have faced financial losses since the implementation of UC. A study suggested that approx. 70% of public hospitals faced losses after one year of UC implementation (Ngorsuraches & Sornlertlumvanich 2006). In terms of the deviations between proposed and approved capitation rates, UC has faced a continued budgetary shortage since its initiation (Tangcharoensathien *et al*. 2007). Whilst the revenue for UC, however, is based on general tax income, it is not easy to increase UC budget which largely depends on factors outside the health sector (such as economic situations or political agenda).

Given the escalation of health expenditure and UC related hospital losses in Thailand, controlling hospital costs has become vitally important. In this connection, unit costs of hospitals have recently been increasingly studied among public hospitals. However, the underlying structure and characteristics of hospital costs have yet to be well understood, particularly after the UC implementation. Better understandings of costs of public hospitals would have significant implications on policy and decision-makings in the health sector of Thailand. On this ground, the objectives of this study are justified.

1.2 General information of Thailand

1.2.1 Country profile

Thailand lies in the heart of South-East Asia, covering an area of 514,000m^2. With a total population of 65 thousand in 2007, 31.5% of the population lived in urban areas which reflect a significant urbanisation compared to 18.7% in 1990 (see Table 1-2 in the next Sub-section). The administrative units are divided into 76 provinces (including Bangkok Metropolis), 876 districts, 7,258 Tambons (sub-districts), and approx. 67,373 villages.

1.2.2 Health status of the population

The life of the population in Thailand has significantly improved over the last three decades. Table 1-2 presents some of the population indicators of Thailand. Comparing 1960 and 2007, infant mortality rate has decreased from 84.3 to 16.3, and life expectancy at birth increased from 53.64/58.74 years to 68.4/75.2 years (male/female respectively). Dependency ratio decreased from 92 to 50, which owes to the decreasing younger generations with declining fertility rate (MOPH 2007). Population over 60 years increased from 4.5% to 10.5%, which, together with the lowering fertility rate, suggests a shift towards an aging society.

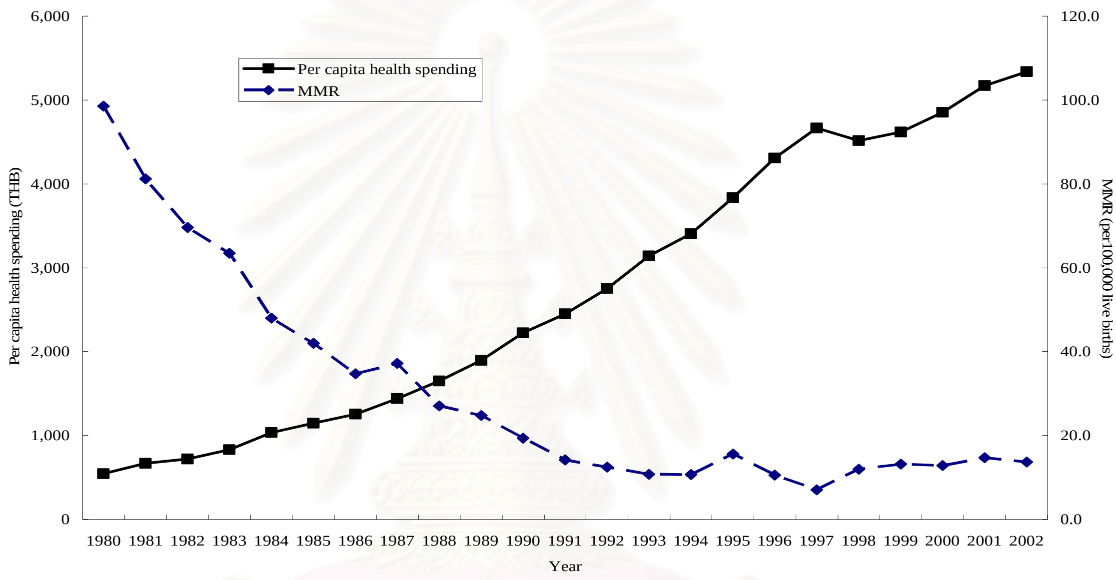
Table 1-2: Basic population indicators of Thailand, 1960−2007

	1960	1970	1980	1990	2000	2007
Total population ('000)	26,260	34,397	44,825	54,548	62,056	65,064
Male	13,154	17,124	22,329	27,062	30,885	31,951
Female	13,104	17,274	22,496	27,487	31,171	33,113
Dependency ratio	92	85	75	57.7	53.3	50.0
Population under 5 years (%)	10.2	16.4	12.1	8.2	8.3	7.5
Population 15–60 years (%)	52.2	49.8	56.4	63.4	60.0	66.8
Population over 60 years (%)	4.5	5.1	5.3	7.4	9.2	10.5
Population in urban areas (%)	12.5	13.2	17.0	18.7	35.0	31.5
Life expectancy at birth (years)						
Male	53.64	57.73	60.25	63.50	70	68.4
Female	58.74	61.57	66.25	68.75	75	75.2
Infant mortality rate (per 1,000 live births)	84.3	56.3	48.0	35.0	22.0	16.3

Source: MOPH 2007

Different factors may have brought about the health improvement of Thai population. Some of such factors may include educational attainment, improvements in living conditions, and increased availability of health resources (Vongsaroj 2004). Even though the health resource is included as one of such contributing factors, however, its degree of contribution to the betterment of population health may be debated from Figure 1-2 where the increase in health expenditure has not necessarily brought about a proportional health improvement.

Figure 1-2: Relations between per capita health spending and health improvement



Source: MOPH 2005

Compared to the 1980s, it is obvious that the health spending during the 1990s has not proportionately contributed to the health improvement of Thai population as measured by maternal mortality ratio (MMR). This situation is consistent with the experience faced by many OECD countries.

The disease pattern in Thailand has shifted from a predominantly communicable nature to non-communicable and life-style related diseases over the past decades. Such a shift requires a major resource reallocation and adjustment which have significant implications on health budget and expenditure. Table 1-3 provides the major burden of disease of Thailand as of 1999.

Table 1-3: Top 10 causes of burden of disease, 1999

Male			Female		
Disease category	DALY	%	Disease category	DALY	%
HIV/AIDS	960,087	17	HIV/AIDS	372,947	11
Traffic accident	510,907	9	Stroke	280,673	6
Stroke	267,567	5	Diabetes	267,158	6
Liver cancer	248,083	4	Depression	145,336	3
Diabetes	168,372	3	Liver cancer	118,384	3
Ischemic heart disease	164,094	3	Osteoarthritis	117,994	3
D (emphysema)	156,861	3	Traffic accidents	114,963	3
Homicide and violence	156,371	3	Anaemia	112,990	3
Suicides	147,988	3	Ischemic heart disease	109,592	3
Drug addiction/harmful use	137,703	2	Cataracts	96,091	2

Source: MOPH 2007

As is evident from the Table, infectious diseases are no longer the major problems for Thai population, even though HIV/AIDS stands out as an exception. Furthermore, many risk factors associated to those diseases with high burden are not controllable within the health sector alone such as traffic accident, homicide and violence, suicides, or drug addictions. It is not difficult to see that resources allocated to services other than medical interventions would play significant roles in reducing the disease burden among the population in Thailand.

1.2.3 Healthcare system

Healthcare is provided by public and private sectors in Thailand. The Ministry of Public Health (MOPH) is responsible for providing, controlling, and supporting all health activities in the country. The majority of public hospitals operate under the umbrella of MOPH, whilst some of them are provided by other Ministries such as Education, Defence, or Interior. In addition to the public sector, the private sector runs different levels of hospitals and clinics. The number of health facilities are summarised in Table 1-4.

Table 1-4: Health facilities in Thailand, 2005

Type	Bangkok	Provinces	Districts	Tambons	Villages
Medical school					
Public	6	5			
Private	1				
Specialised hospitals	19	40			
Regional hospitals		25			
General hospitals					
Public	29	70			
Private	101	244			
Community hospitals	5		724		
Private clinics	3,603	12,944			
Health centres / branches	61/82		214	9,720	
PHC centres		3,108			66,223
(Village health volunteers)					(801,050)
1st class drug stores	3,672	5,186			
2nd class drug stores	479	4,031			
Groceries selling medicines					400,000

Source: MOPH 2007

The ratio of beds to population was 1:223 for Bangkok, and 1:468 for all provinces (MOPH 2007). The physician to population ratio ranged from 1:867 in Bangkok to 1:7,015 in the Northern region (*ibid.*), which reflect a significant maldistribution of health workforces.

1.2.4 Healthcare financing

Prior to the implementation of UC, 20% of Thai population was not covered by any forms of health insurance (*ibid.*). Healthcare financing in such an era was characterised by fragmented public insurance schemes and out-of pocket payment, which resulted in inequitable health services provision. Since the launch of UC in 2002, however, virtually all Thai citizens gained access to healthcare services. The previously fragmented healthcare financing systems have now been merged to three major schemes: civil servants medical benefit scheme (CSMBS); social security scheme (SSS); and UC. The characteristics of each scheme is provided in Table 1-5.

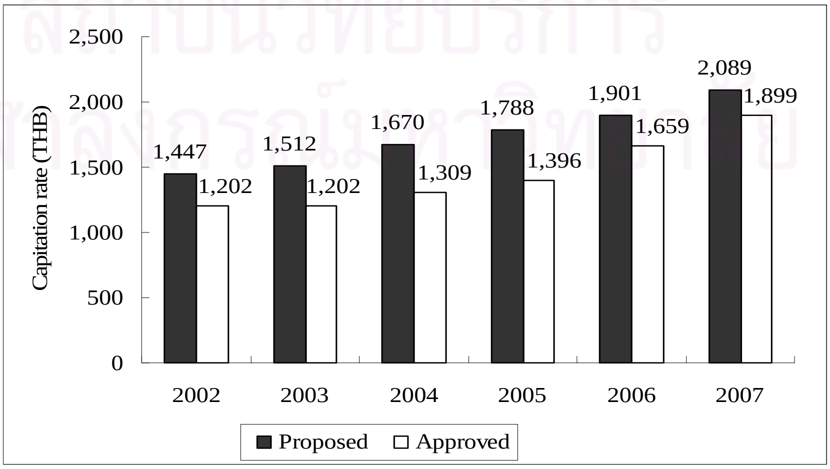
Table 1-5: Characteristics of healthcare financing schemes, 2002

Characteristics	CSMBS	SSS	UC
Population coverage	10 mil.	7 mil.	45 mil.
Beneficiaries	Civil servants and their families	Private formal sector employees	People not covered by CSMBS or SSS
Source of fund	General tax	Tripartite, 1.5% of payroll each	General tax
Financing body	Ministry of Finance	Social Security Office	National Health Security Office
Payment mechanism	Fee for service	Capitation	Outpatient: Capitation Inpatient: DRG
Choice of provider	Free choice (public)	Registered public/private	Registered public/private

Source: MOPH 2007

Despite its benefit of UC to the Thai citizens who had never been covered by any form of insurance, the scheme itself poses a question on financial sustainability in its implementation. As is shown in Figure 1-3, there has been five years consecutive deficit of UC capitation. Whilst the approved capitation rates have been increasing over years, so has the cost per capita. This is the major cause of hospital loss which summed up to THB 1,387 million in 2004 (MOPH 2007).

Figure 1-3: UC capitation: proposed vs. approved, 2002−2007



Source: Tangcharoensathien *et al*. 2007

1.3 Research question

What are the cost structure and characteristics of public hospitals in Thailand?

1.4 Research objectives

Overall objective:

To analyse the cost structure and characteristics of public hospitals in Thailand.

Specific objectives:

- To estimate the hospital cost function with a flexible functional form.
- To explore an econometric model to estimate unit costs of inpatient and outpatient services.
- To discuss the existence of economies of scale & scope among public hospitals.

1.5 Benefits of the study

Potential beneficiaries of this study may include: MOPH; healthcare purchasers (Ministry of Finance, Social Security Office, and National Health Security Office); public hospitals (provincial and community levels); and scholars involved in health policy and economic research. The findings of this study are expected to inform researchers, policy makers and decision makers at different levels in the following manner:

Cost function

- To provide information for resource planning on public hospitals at macro and micro levels;
- To enable impact simulations on public hospitals' total costs with different scenarios in output/input mix;

- To provide evidence whether public hospitals should be larger or smaller in size;
- To provide evidence whether public hospitals should provide a broad range of services or should specialise in a narrow range of services;
- To provide a "rough" idea on technical efficiencies of public hospitals by comparing actual vs. estimated total costs;

Unit cost estimation

- To provide information for resource planning on public hospitals at macro and micro levels (in conjunction with the cost function);
- To enable impact simulations on public hospitals' unit costs with different scenarios in output/input mix (in conjunction with the cost function);
- To provide hospital unit cost information for economic evaluations (in conjunction with the cost function); and
- To provide basic information for discussions on allocative efficiencies of public hospitals by comparing actual vs. computed unit cost ratios.

CHAPTER II

LITERATURE REVIEW

2.1 Policy implications of hospital costs

Parallel to its significant share in health expenditure, hospitals have been seen with scepticism in terms of efficiency (Bitran-Dicowsky & Dunlop 1989; Barnum & Kutzin 1993; World Bank 1993). Many public health experts have argued that more health resources should be shifted from hospital-based treatment to more preventive and primary cares to improve efficiency in resource use.

Such believes, however, are not self-evident in themselves which require various kinds of studies. The cost of hospital is one of such issues to be investigated. Hospital costs have been extensively studied in high-income countries over the past decades, particularly in the USA, where the escalation of health expenditure has been prominent. Many of such studies have focused on estimating hospital cost functions and unit costs. However, little has been known about hospital costs in developing countries (Adam *et al*. 2003; Weaver & Deolalikar 2004; Alba 1995).

Wagstaff & Barnum (1992) suggest four kinds of policy questions which the analyses of hospital cost functions may be able to answer:

- Are hospitals over-capitalised;
- Are hospitals inefficient;
- Should hospitals specialise or provide a broad range of services; and
- Are there too many hospitals (too many small-sized hospitals which should be merged to larger hospitals).

Such policy questions may be commonly raised in any county irrespective of income levels. Findings from high-income countries provide varied policy implications which imply that the characteristics of hospital costs are context specific. However, some common features may be derived from past studies (Smet 2002, p.905):

- Hospitals are not operating in their long-run equilibrium and are mostly over-capitalised (which favour the use of short-run cost functions);
- The number of physicians tend to be excessive or they tend to over-use resources;
- Ray economies of scale exists at sample means even though they would be quickly exhausted; and
- Findings on economies of scope are mixed and generally inconclusive.

These features identified in high-income countries may or may not be applicable to other settings. However, the same econometric estimation techniques used for studies in those countries could equally be useful for low and middle-income countries (Wagstaff & Barnum 1992). Nonetheless it should be noted that the different natures of healthcare systems, such as the domination of public hospitals or private hospitals, and varied availabilities of necessary data may require some adjustments in their applications.

Unit cost, which is often expressed in terms of per inpatient-day, inpatient-case (admission or discharge), and outpatient visit, is another key element for different kinds of policy decisions (Adam & Evans 2006). Adam *et al*. (2003) suggest three applications of unit cost information on decision-making:

- Budgeting and planning;
- Efficiency assessment of hospitals; and
- Economic evaluations (cost-effectiveness, cost-utility, cost-benefit analyses).

Whilst the calculation of unit costs is an established method, many calculations are derived from specific medical researches and hence may not necessarily be generalisable for further use in other settings (Oostenbrink 2003). In developing countries, unit cost information itself is not always available due to resource constraints (Adam *et al*. 2003; Adam & Evans 2006).

2.2 Past studies on hospital cost function analysis

In general, two branches of hospital cost function specifications have been applied in empirical studies. One of the forms used in earlier studies is the "ad hoc" functional specification where the researchers investigated the determinant factors of variations in average costs (Breyer 1987). Another type of specification is based on the "neo-classical production theory" whereby outputs and inputs are the main determinants of the cost of production. The following describes the different specifications and the underlying assumptions of each functional form with references to some examples from past literatures[1].

2.2.1 Ad hoc cost function

For an ad hoc specification, average cost is typically used as the dependent variable, while all kinds of factors hypothesised to be associated with cost are included as regressors. The average cost is primarily selected for convenience rather than on theoretical ground, since the use of total cost as dependent variable may cause econometric inconvenience where heteroskedasticity may bias the parameter estimation (*ibid.*).

Whilst this form of cost function is able to account for the large heterogeneity of

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1 The summary and comparison of past studies are provided in Appendix A.

hospital outputs without drastically increasing the number of parameters, a major trade-off is made in terms of flexibility such as separability (Smet 2002). Due to its absence of theoretical background, the simplest additive-linear form has frequently been applied such as

$$AC = \alpha_0 + \sum \beta_i X_i + e$$

where AC denotes average cost, X_i the vector for different regressors, e the random disturbance, and the Greek letters represents the parameters. A major disadvantage of this specification is that the average cost is used as the dependent variable which only allows for a single output to enter the function. This ignores the multiple output nature of hospital services which may lead to a serious misspecification of the function. Other weaknesses of an ad hoc function may include: output entering on both sides of the equation; and the lack of theoretical justification for inclusions of some explanatory variables (Bitran-Dicowsky & Dunlop 1989). The following list represents several kinds of regressors which have been used in past studies with ad hoc functional forms (Breyer 1987, p.148):

- capacity (number of beds) of the hospital;
- case flow rate, average occupancy rate, or average length of stay;
- case mix;
- wage levels of hospital employees,
- dummy variables for teaching status (with or without), the existence of a nurses' training program, and ownership type,
- indicators of hospital facilities and services,
- characteristics of the market surrounding the hospitals such as regional income levels, physician density, or hospital bed density.

Lave *et al*. (1972) analysed the cost of 65 hospitals in the USA from 1968 and 47 from 1967, mostly from Western Pennsylvania. The main purpose of this study was to provide the cost information for an incentive reimbursement plan for non-governmental hospitals. Cost per inpatient was used as the dependent variable and incorporated a linear specification. The variables were classified into two categories: characteristic variables (C); and diagnosis mix variables (D). There were 15 C variables incorporated such as number of beds, occupancy rate, length of stay, teaching status etc. D variables were grouped to 17 variables based on ICDA classification system. Since multicollinearity was perceived as a major threat to the analysis, parameters were reduced by using principal component analysis technique. The study included case-mix adjustment by the inclusion of a surgical difficulty index. The finding revealed that the complexity of case-mix to be related to higher average cost, as had been anticipated, whilst teaching status was negatively correlated perhaps due to lower labour cost incurred for students' services.

2.2.2 Neo-classical cost function

Another spectrum of cost function specification is those based on the neo-classical economic theory. The cost function is defined, as can be found elsewhere in economic textbooks, as the minimum cost to provide a certain level of output given the input prices as exogenous vectors (and capital stock in case of short-run). Output prices may have a role for a multi-product cost function, which can affect the levels of output mix. The structural model strictly follows this theory and there are no rooms for other variables to enter the function. The theory requires the restrictions of non-decreasing and homogeneity of degree one in the input prices.

Flexible functional forms are most frequently used under the neo-classical theory.

There are numbers of models available for flexible cost functions. The following functional forms have typically been used in empirical studies of cost functions with multi-product nature, including hospitals (Caves *et al*. 1980; Guilkey *et al*. 1983; Smet 2002):

- Generalised Leontief function;
- Transcendent logarithm (translog) function;
- Generalised translog function;
- Quadratic function; and
- Hybrid function.

Generalised Leontief function

Generalised Leontief function was proposed by Diewert (1971) as a path-breaking model of flexible cost functions. He, at the same time, proposed a generalised linear production function. Hall (1973) suggested that these two functions can be combined to give rise to a hybrid Diewert cost function (or generalised linear – generalised Leontief cost function) of which the specification is given as

$$C = \sum\sum\sum\sum \alpha_{ijkl} Y_k Y_l^{1/2} W_i W_j^{1/2} + e$$

where C denotes total cost, Y_k and Y_l the outputs, W_i and W_j the price of inputs, e the random disturbance, and the Greek letters the parameters. The functional form is linearly homogeneous in input prices by construction (Guilkey *et al*. 1983). The restriction on constant returns to scale is generally imposed between output and total cost relationships (Caves *et al*. 1980).

Li & Rosenman (2001) used the generalised Leontief function in estimating a long-run cost function using a panel data set of 90 Washington State hospitals in the

USA during 1988−1993. Despite the major drawback of increasing parameters, the restriction on constant returns to scale was not imposed in order to account for measurement of scale economies. The study measured the outputs by inpatient days and outpatient visits. Other intermediate outputs, such as surgery, physical therapy, radiology etc., were treated as inputs in order to capture the substitution between intermediate outputs rather than between capital and labour (or types of labour). This was made possible by aggregating the labour input prices by intermediate output areas rather than by professional categories (such as price of physician, nurse, pharmacist etc.). Whilst the individual parameters in a generalised Leontief function do not provide sufficient information to be interpreted, the main focus has been the substitutability among different inputs, particularly intermediate outputs. Feasible generalised least squares method was used for the analysis to improve efficiency of parameter estimation. Economies of scale was identified, whilst economies of scope was inconclusive. An interesting finding was that outpatient services were complementary to core inpatient services, which discourages stand-alone outpatient clinics which are likely to result in increased cost.

Translog function

The translog function, which was proposed by Christensen *et al*. (1973), has been the most popular form of a flexible cost function in empirical studies. The specification of a translog cost function can be described as

$$\begin{aligned} lnC = \; & \alpha_0 + \sum\beta_i lnY_i + 1/2\sum\sum\beta_{ij} lnY_i lnY_j + \sum\gamma_i lnW_i + 1/2\sum\sum\gamma_{ij} lnW_i lnW_j \\ & + \sum\sum\delta_{ij} lnY_i lnW_j + e. \end{aligned}$$

The duality theorem requires the imposition of restriction in factor prices to be linearly homogeneous of degree one.

A study undertaken by Cowing & Holtman (1983) pioneered the application of translog cost functions to hospital settings. 138 hospitals from the USA in 1975 were analysed in their study. The total variable cost was used as the dependent variable, which was regressed by five outputs, six input prices, capital, number of admitting physicians, and dummy variables to derive a short-run cost function. Capital was handled as fixed inputs where the book value of buildings and equipment was used. The result indicated the existence of economies of scale, a mixed economies and diseconomies of scope, whereas over-capitalisation was prevalent in most of the sampled hospitals. Whilst the finding of economies of scale supported the policy of some states to close down numbers of hospitals and concentrate in fewer large hospitals, Vita (1990) provided some arguments against such findings in that the scale parameters did not correspond to a movement along a long-run cost function but actually on a short-run function, and hence did not reflect the true scale economies. Furthermore, the interpretation of over-capitalisation was challenged by Wagstaff & Barnum (1992) of which the details will be given in Chapter IV.

Conrad & Strauss (1983) used the translog function to estimate the hospital cost function in the USA, where 114 North Carolina hospitals in 1978 were analysed. It incorporated three output variables and four input prices to regress total cost to derive a long-run cost function. Due to the nature of a translog function, where many parameters are to be estimated even for a small number of output and input variables, cost share equations derived from Shephard's lemma were simultaneously estimated together with the cost function in order to avoid inefficient estimations due to multicollinearity. The result indicated complementarities of nurses, technicians, and other specialised labour with capital, which explained the escalation of hospital costs with the introduction of high-technology capitals.

Generalised translog function

One of the flaws of a translog function is its incapability in dealing with a sample with "zero output", since the natural logarithm for zero is not defined. The generalised form of translog function can successfully overcome this limitation by applying the Box-Cox transformation (Box & Cox 1964) to the output variables. With this transformation, zero output can be accounted for in the translog function (Caves *et al*. 1980). The form of a generalised translog function is written as

$$lnC = \alpha_0 + \sum\beta_i[(Y_i^{\lambda}-1)/\lambda] + 1/2\sum\sum\beta_{ij}[(Y_i^{\lambda}-1)/\lambda]\,[(Y_j^{\lambda}-1)/\lambda]$$
$$+ \sum\gamma_i lnW_i + 1/2\sum\sum\gamma_{ij} lnW_i lnW_j + \sum\sum\delta_{ij}[(Y_i^{\lambda}-1)/\lambda]lnW_j + e$$

where λ denotes the Box-Cox parameter. If λ is set sufficiently small, $[(Y_i^{\lambda}-1)/\lambda]$ approximates lnY_i, yet able to account for Y=0 case.

The generalised translog cost function was employed by Vita (1990) to analyse 296 Californian hospitals in 1983, USA. This form of cost function is used to account for zero outputs of sampled hospitals. Total variable cost was used as the dependent variable, which was regressed by five outputs and five input prices to derive a short-run cost function. Number of beds was used as the proxy for fixed input which determined the cost-minimising levels of variable inputs. Five cost share equations were derived using Shephard's lemma, which were jointly estimated by maximum likelihood method. The author provides some discussions on the limitation of a translog model where the cost behaviour for output levels outside the neighbourhood region of approximation point is not accurately estimated. This leads to the suggestion that the translog model not to be used for policy questions which involve large, discrete changes in output levels such as merger and consolidation of hospitals.

Quadratic function

Quadratic function resembles a similar form as translog function whereby the quadratic form is retained but do not embrace the logarithmic transformation. Its specification is described as

$$C = \alpha_0 + \sum\beta_i Y_i + 1/2\sum\sum\beta_{ij} Y_i Y_j + \sum\gamma_i W_i + 1/2\sum\sum\gamma_{ij} W_i W_j + \sum\sum\delta_{ij} Y_i W_j + e.$$

In this form, the output specific marginal costs can be directly derived by taking the derivatives of cost with respect to each output (Hansen & Zwanziger 1996). This is in contrast to a translog function where the derivatives will derive the elasticities of cost with respect to each output rather than the marginal cost. A major drawback of a quadratic form is that it does not satisfy the linear homogeneity in input prices which could only be imposed by sacrificing its flexibility (Caves *et al*. 1980).

Hansen & Zwanziger (1996) employed the quadratic functional form to compare the marginal costs of general acute hospitals in the USA (California and New York) and Canada. The study analysed the cost of hospitals for two years. In 1981, 394 hospitals from California, 185 from New York, and 271 from Canada were examined, whereas 383 from California, 180 from New York, and 269 from Canada were included for 1985. Ordinary least squares (OLS) method was used to estimate the parameters, which was then recalculated by generalised least squares (GLS) after detection of heteroskedasticity. The result indicated significant differences between the three groups. Canadian hospitals performed at lowest cost for both acute and intensive cares, whilst California was almost three times as high as Canada. Testing for scale effects revealed a very mild effect in each case. California exhibited a mild economies of scale for intensive care, whilst acute care indicated diseconomies of scale. Canada revealed a reverse pattern, and the effect in New York was almost negligible. However, the limitations of the study included that it did not account for case-mix differences due to data limitation for Canadian hospitals. Evans (1971) pointed out in his study that the absence of case-mix adjustments can cause bias which could result in an exaggerated diseconomies of scale.

Hybrid function

An attempt to incorporate desirable features of both an ad hoc function and a neoclassical structural function gave rise to a hybrid functional form. There is no agreed specification for this kind of functions and can be combined with various forms including ad hoc and flexible functions. However, a common characteristics rests with its consistency with economic theory where the assumption of linear homogeneity in input prices is maintained whereby cost and input prices are logged, yet various regressors other than output and input are incorporated (Smet 2002). Such other variables do not define the cost-minimum but may explain the variations of costs among different hospitals.

Grannemann *et al*. (1986) was the first to apply the hybrid functional form by investigating the cost of 867 hospitals in the USA as of 1981. Input prices were not interacted with output variables due to the already large number of parameters, particularly for outputs, and poor quality of input price data. This implicitly imposed another restriction in that the associated production function to the cost function by duality was homothetic, or, in other words, the cost-minimising mix of inputs is independent from the output levels. The large sample size enabled the estimation of 64 parameters by OLS method to derive a long-run cost function. The large number of insignificant estimates of parameters, however, may indicate a severe multicollinearity which is another issue to be handled in a flexible functional form.

Another limitation of this study was its violation of the regularity conditions of duality theorem where the negative sign of the wage of lab technician did not meet the requirement of non-decreasing condition (Breyer 1987). The impact of this issue might be sufficient to bias the finding of the study.

A similar form to the one used by Grannemann *et al*. (*ibid.*) was employed by Weaver & Deolalikar (2004) to analyse economies of scale and scope of Vietnamese public hospitals. The study used 597 public hospitals in Vietnam, which involved six categories and broad range of sizes. Input prices were not included because: the information was rarely available; and its omission was deemed not to bias the result due to the centrally standardised salary scale for staff in public hospitals. The proportion of bonus in terms of staff payment, on the other hand, was tested for its inclusion as a proxy for input prices. However, the inclusion had to compromise the sample size due to missing data and anyway the parameter turned out to be insignificant. The result revealed that there were significant differences in cost levels between regions, levels, and category of hospitals. Economies of scope between outpatient and inpatient services were identified for all hospitals even though it was prominent for general hospitals compared to specialised and district hospitals of which the effects were almost zero. Findings on economies of scale were rather mixed which included diseconomies of scale for provincial hospitals, and minor to negligible economies of scale for central and district hospitals. The addition of interaction terms between capital stock (number of bed) and dummies on category of hospitals improved the fit of the model. These findings imply that the returns to scale of hospitals depend on the category of hospitals as much as their capacities.

Other studies which employed this type of specifications can be found in several studies conducted in developing countries under the initiative of the World Bank.

Such studies included Bitran-Dicowsky & Dunlop (1989) for Ethiopia and Barnum & Kutzin (1993) for Columbia and China. Common to all these studies, however, the input prices were not included due to similar reasons mentioned above: reliable data were not available; proxies used to capture price variations turned out to be statistically insignificant; and the centrally standardised personnel wage levels could be assumed to be homogeneous across hospitals, which did not cause bias to answer the research questions.

Long-run vs. short-run cost functions

Most of the neo-classical cost-function studies focus on either long-run or short-run. Various discussions have been provided on the preference of one over the other. One of the major differences between these two views rests with the assumption on capitals. Grannemann *et al*. (1986) used the long-run cost function by treating the capital as a variable factor which hospitals have the capabilities to adjust according to demand. On the other hand, others assumed that the hospitals were not capable in adjusting the capitals to the cost-minimising levels, and so preferred the short-run cost function (Cowing & Holtman 1983; Vita 1990; Weaver & Deolalikar 2004). Smet (2002) discussed that the short-run cost function is theoretically more appealing since the use of a long-run specification without testing for long-run equilibrium may lead to estimation bias.

Aletras (1999) compared both long-run and short-run cost functions in his study to explore the economies of scale among 91 public hospitals in Greece. Translog cost function was used in this study. However, the variables on input prices were not included because such data were not available. The effect of the omission of input prices was considered negligible since the wages of staff members are uniformly set based on each category, and the price for supplies was also assumed to be uniform due to a common national bidding system. In addition to inpatient cases and outpatient visits, case-mix index and a dummy for teaching status were added to the model.

In both long-run and short-run specifications, all the second-order output parameters turned out to be highly insignificant. The author discussed that the translog function was rejected and the Cobb-Douglas form was favoured. The analysis on economies of scale provided contradictory results, which were significant in the long-run but insignificant in the short-run. The author discussed which specification was favoured over the other in the analysis. The positive sign of the number of bed in the short-run specification was interpreted as evidence that the capital was not set at the cost-minimising level. The author hence rejected the long-run cost function and favoured the short-run, which suggested that there were no economies or diseconomies of scale, and hence the prospective reimbursement system in Greece should not account for the effect of scale economies. This interpretation of capital, however, is debated among researchers which will be discussed in Chapter IV.

2.3 Past studies on econometric estimation of unit costs

Accounting-based method, such as step-down or simultaneous allocation, is a desirable technique for unit cost estimation. However, its costly and time consuming nature often hinders its application for quick decision-makings. Due to this limitation, some studies were opted to use a simple rule-of-thumb where the hospital costs are assigned to inpatient or outpatient services by a certain proportion such as 4 outpatient visits = 1 bed-day, and then estimated the unit cost from full costs by applying the proportion (Adam & Evans 2006). However, there is a limitation in this method that the proportion is arbitrary and can vary among hospitals.

Given this shortfall, WHO has developed two econometric models for hospital unit cost estimation globally alongside the recent CHOICE Project (CHOosing Interventions that are Cost-Effective). The first model was aimed at estimating the unit cost per inpatient bed-day from GDP per capita, occupancy rate, levels and ownership of hospitals (Adam *et al.* 2003). The second model analysed the determinant factors of the ratio of unit cost per inpatient bed-day versus outpatient visit where GDP, occupancy rate, and number of hospital beds were identified (Adam & Evans 2006.). The combination of these models enabled to estimate the unit cost per outpatient visit from the inpatient unit cost estimated by the first model.

The first model used the Cobb-Douglas functional form to approximate the normal-distribution of the model variables. The function took the form of

$$ln\text{UCIP} = \alpha_0 + \sum \alpha_i X_i + e$$

where UCIP denotes the unit cost of inpatient bed-day, X_i the explanatory variables such as GDP per capita (log), occupancy rate (log), and different dummies which affect the levels of costs. Data from 49 countries between 1973−2000 with 2,173 country-years were analysed. Average cost per inpatient bed-day was used as the dependent variable and various explanatory variables other than outputs and input prices entered the regression model. Therefore it is comparable to an ad hoc cost function described in the previous Sub-section. Whilst neoclassical cost functions have been preferred to describe the hospital costs by most recent studies, two potential reasons might have hindered its application to this study. First, the necessary information for a neo-classical cost function, such as input price, was generally not available in study reports on hospital unit costs. Second, since the estimated costs by a flexible function for varied sizes of hospitals from the average ones often severely deviate from the actual costs, its application might have been discouraged for a study where the main focus was the estimation of costs rather than to answer other policy questions.

The second model used the natural logarithmic transformation of unit cost ratio between outpatient services and inpatient services as the dependant variable:

$$ln(\text{UCOP}/\text{UCIP}) = \beta_0 + \sum\beta_i X_i + e.$$

Data from 28 countries between 1980−2000 with 2,415 hospital-years were analysed. The variables were similar to those used in the first model, which were selected based on availabilities. The double log form was selected to avoid heteroskedasticity, and hence neither the specification nor the explanatory variables were based on theoretical backgrounds. Whilst the study developed a relatively sound model to estimate the unit cost ratio, additional explanatory variables could improve the accuracy of estimations. Some potential variables may be suggested for the model, if available, such as average length of stay, number of doctors per bed, teaching status, case-mix index etc. Even though such data might be routinely available in many countries, the less availability of accounting-based unit cost data may hinder the link between the dependent variable and explanatory variables. In this connection, the model developed in this study could be considered as the best possible attempt under the limited information and theory, and is at least valuable for countries without any information on unit costs.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Study design

This is a descriptive study employing econometric techniques for its analysis. A cross section model with secondary data from the year 2006 was used for the cost function analysis. The unit cost estimation models were analysed using data obtained from different studies undertaken in the past between 1998–2003.

3.2 Target and study population

Cost function

The target population included all public hospitals in Thailand. Regional and higher specialised hospitals, however, were not included in the study due to the perceived differences in cost structure and characteristics particularly owing to teaching and research status. Private hospitals were not included due to the difficulties in obtaining data, despite its drawback in that the study is not able to describe the entire hospital market. Out from the inclusion and exclusion criteria above, 828 community and provincial hospitals were considered as the study population. Data were available for 787 hospitals from 69 provinces as of 2006 at MOPH. Out of them, 83 hospitals were excluded due to missing data on either total cost or input prices, which left 704 hospitals as the study sample.

Unit cost estimation

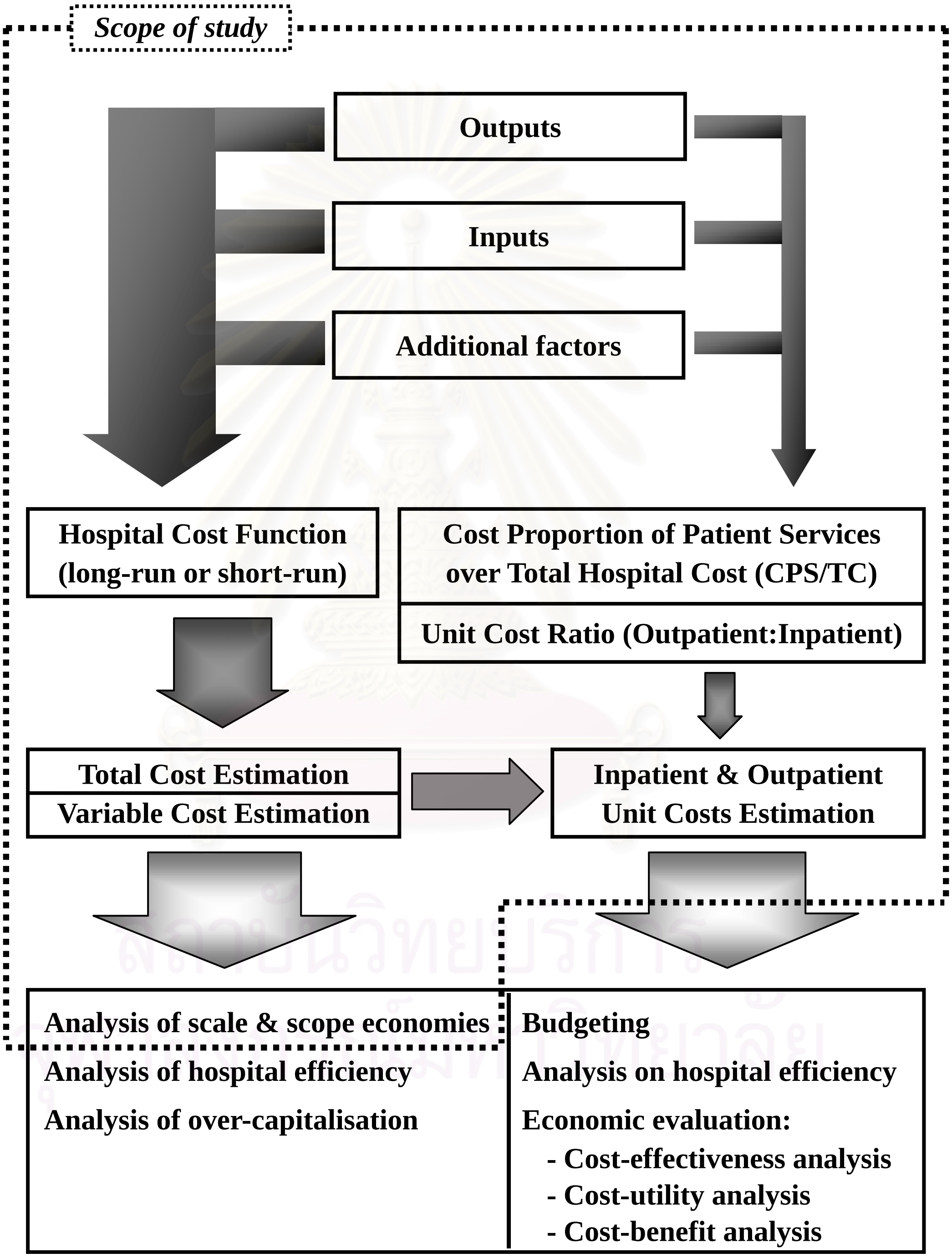
Data on unit costs was expected to be obtained from MOPH together with those used for the cost function analysis. However, the unit cost data so obtained were not based on accounting-based exercises, but were estimated by applying the "rule-of-thumb" where the unit costs for inpatient were assumed to be 14 or 18 times as high as the ones for outpatient for community hospitals and provincial hospitals, respectively. Therefore, the unit cost data and the corresponding data of explanatory variables had to be obtained from past study reports. Due to logistic and time constraints, the analysis was conducted by using data of 23 sample hospitals from different provinces and years.

Using data from different years may be justified under the assumptions that the cost ratio is independent from the price levels between years, and that the technological advancement over years equally affect the costs of outpatient and inpatient services. On the other hand, there may be some effects from the changes in health systems such as before/after the UC implementation. This issue may be accounted for by adding a dummy variable in the regression model to distinguish pre/post UC. However, a high correlation between the two dummy variables on UC patient proportions for inpatient and outpatient services were identified in the cost function (see Sub-section 4.2.1), and so it was assumed that the UC also affects the cost of inpatient and outpatient equally. Therefore the inclusion of another dummy variable in this model was not considered worth trading off the degrees of freedom. In this connection the compromise of using the sample data from different years is justified for this study.

3.3 Conceptual framework

The conceptual framework of this study is provided in Figure 3-1.

Figure 3-1: Conceptual framework



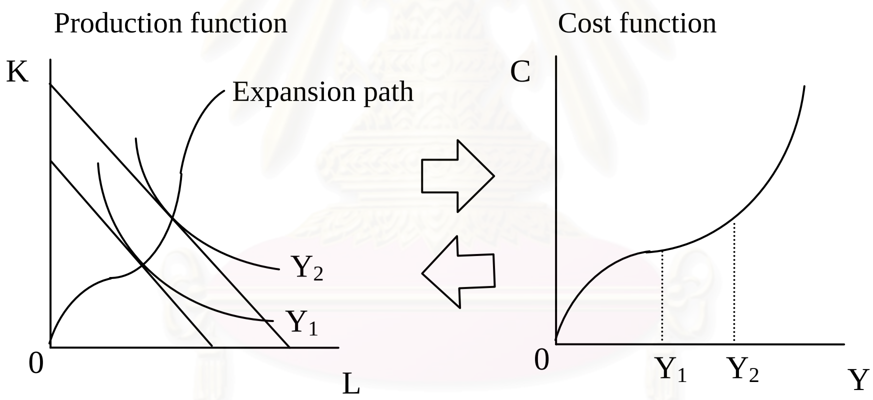
3.4 Functional models

3.4.1 Theoretical framework

Long-run cost function

Whilst a production function describes the relationship between inputs and outputs, cost functions describe the relationships between outputs and costs. These two functions have mutual relationships to the other, which can be graphically presented as per Figure 3-2.

Figure 3-2: Production and cost (long-run)



The (total) cost function is derived from the expansion path of a production function, which represents the cost-minimising input mix (L denotes labour and K denotes capital) to produce a certain level of output (Y), given the input prices (Coelli *et al.* 1998). The duality theorem between cost and production functions proposed by Shephard states that the other direction is also true that the underlying production function can be derived from the overarching cost function (Diewert 1971). Such duality, however, are subject to certain regularity conditions whereby the cost function must be (*ibid.*):

1. a positive real valued function;
2. a non-decreasing left continuous function in outputs;
3. a non-decreasing function in input prices;
4. linear homogenous in input prices for every outputs; and
5. a concave function in input prices for every outputs.

Particularly conditions 2 and 4 deserve due attentions in empirical econometric analyses which must be investigated before progressing any further. It must be noted that K is not able to be adjusted at the cost-minimising level in the short-run, and hence the cost-minimising logic assumes a long-run cost function. Based on this assumption, we consider the total cost as

$$C = wL + rK \quad (3\text{-}1)$$

where w represents the price of labour and r the price of capital. Under the assumption that the mix of L and K are adjusted to the cost-minimising levels to produce output quantity Y, the long-run cost function can be expressed as

$$C = f(Y,w,r). \quad (3\text{-}2)$$

The constrained cost minimising input mix, given output Y and fixed input prices w and r, can be derived in two ways (*ibid.*). One way is to apply the Lagrangean technique in a production function to derive the demand functions for input factors. Another way is to use the Shephard's lemma by partially differentiating the cost function with respect to input prices provided that it satisfies the regularity conditions. The conditional factor demand function derived in this way will yield:

$$\partial C/\partial w = L(Y,w,r); \text{ and}$$

$$\partial C/\partial r = K(Y,w,r). \quad (3\text{-}3)$$

Alternatively if we differentiate the cost function logarithmically, it will yield the cost shares of factor inputs (Coelli *et al*. 1998):

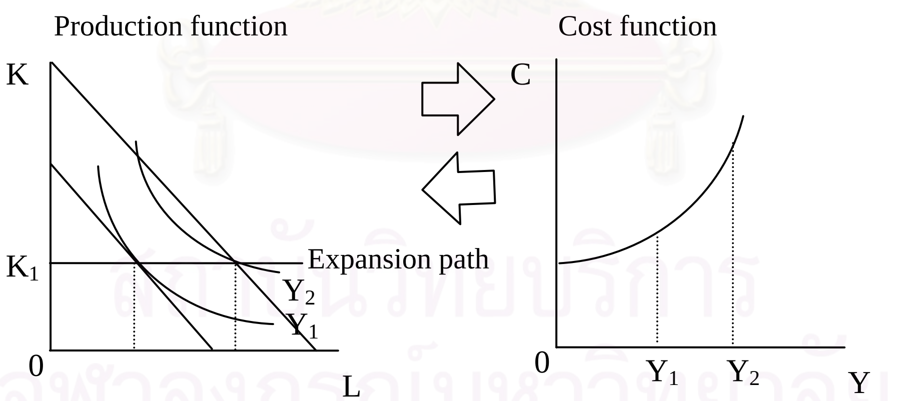
$$\partial lnC/\partial lnw = (\partial C/\partial w)(w/C) = Lw/C = S_L\text{; and}$$

$$\partial lnC/\partial lnr = (\partial C/\partial r)(r/C) = Kr/C = S_K\,. \qquad (3\text{-}4)$$

Short-run cost function

On the other hand, it may be reasonable to assume that the firm is not operating at the cost-minimising level of input mix in a short-run. In a short-run cost function, K, which is fixed in the short-run, is not necessarily adjusted to the optimal level, and hence the assumption for quantity L, which is variable in the short-run as well, is assumed to be adjusted to the cost-minimising level conditional to the given level of K. Therefore the production and cost functions may be described as Figure 3-3.

Figure 3-3: Production and cost (short-run)



If we assume the total cost as

$$C = VC + FC = f(w_1,w_2,K) + rK \qquad (3\text{-}5)$$

where VC represents the variable cost, FC the fixed cost, and w_1 and w_2 the cost minimising variable inputs given K, we derive the short-run variable cost function:

$$VC = f(w_1,w_2,K). \quad (3\text{-}6)$$

The conditional factor demand function and the cost shares of factor inputs can be derived in the same manner as for a long-run.

Unit cost estimation (accounting-based method)

The ideal method to estimate the unit costs of hospitals is the accounting-based method. Whilst a detailed description of this method would be exhaustive, the four steps involved in this method are described below[1]:

1) Cost centre identification;
2) Compiling total direct cost;
3) Defining allocation criteria; and
4) Full cost and unit cost estimation.

Step 1 is to identify the cost centres based on the organogram and classify them into one of four categories: Revenue Producing Cost Centre (RPCC); Non-revenue Producing Cost Centre (NRPCC); Patient Services (PS); and Non-patient Services (NPS). In Step 2, the direct cost of each of the four cost centres will be identified. Once the direct costs have been identified, Step 3 defines the criteria to allocate the overhead costs (RPCC and NRPCC) to PS and NPS. In Step 4 the overhead costs are allocated to PS and NPS, and the full cost of PS will be further divided into inpatient and outpatient services (division can be more detailed depending on the purpose of each study). Finally the full costs of inpatient and outpatient services will be divided by the quantity of each output to obtain the unit costs. The framework of this procedure is described in Figure 3-4.

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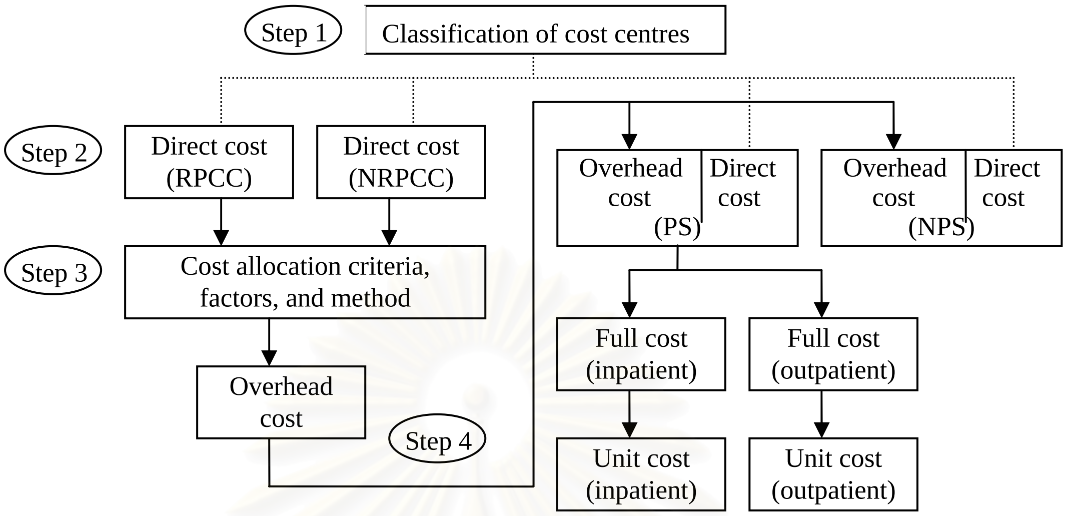
[1] See Tisayaticom *et al*. (2007) for details.

Figure 3-4: Accounting-based unit cost estimation framework



3.4.2 Models for the cost function

A flexible function was preferred over an ad hoc function in this study. The major drawback of a flexible function is the large number of parameters even for a small number of variables. However, the theoretical justification and its applicability to analyse different policy questions suggested the use of this form over the other. Amongst several alternatives for a flexible function, the specific form may be selected based on goodness of fit. In this study, however, a hybrid translog form was favoured due to the following reasons:

1. The translog model has the smallest number of parameters which is still manageable (unlike the generalised Leontief function);
2. The homogeneity in input prices can be easily imposed without increasing the number of parameters to be estimated (unlike the quadratic function);
3. Hybrid characteristics allow for analysing various factors other than outputs and input prices which are potentially correlated to the level of hospital cost (such as case-mix or patient characteristics); and

4. Economies of scale & scope, which form part of the objectives of this study, can be easily estimated from a translog function.

Translog cost function

A translog multi-product cost function (TMCF) featuring hybrid characteristics was assumed in this study whereby variables other than output and inputs hypothesised to be correlated with cost also entered as regressors. The specifications for the long-run and short-run cost functions are:

Long-run

$$lnTC = \alpha_{t0} + \sum_{i=1}^{3}\beta_{ti}lnQ_i + 1/2\sum_{i=1}^{3}\sum_{j=1}^{3}\beta_{tij}lnQ_ilnQ_j + \sum_{i=1}^{6}\gamma_{ti}lnP_i + 1/2\sum_{i=1}^{6}\sum_{j=1}^{6}\gamma_{tij}lnP_ilnP_j + \sum_{i=1}^{6}\sum_{j=1}^{2}\delta_{tij}lnP_ilnQ_j + \sum_{i=1}^{3}\eta_{ti}F_i + \sum_{i=1}^{4}\varphi_{ti}D_i + \varepsilon_t \qquad (3\text{-}7)$$

Short-run

$$lnVC = \alpha_{v0} + \sum_{i=1}^{3}\beta_{vi}lnQ_i + 1/2\sum_{i=1}^{3}\sum_{j=1}^{3}\beta_{vij}lnQ_ilnQ_j + \sum_{i=1}^{5}\gamma_{vi}lnP_i + 1/2\sum_{i=1}^{5}\sum_{j=1}^{5}\gamma_{vij}lnP_ilnP_j + \sum_{i=1}^{5}\sum_{j=1}^{2}\delta_{vij}lnP_ilnQ_j + \kappa_{v1}lnK + 1/2\kappa_{v11}(lnK)^2 + \sum_{i=1}^{2}\pi_{vi1}lnQ_ilnK + \sum_{i=1}^{5}\tau_{vi1}lnP_ilnK + \sum_{i=1}^{3}\eta_{vi}F_i + \sum_{i=1}^{4}\varphi_{vi}D_i + \varepsilon_v . \qquad (3\text{-}8)$$

where TC = total cost;

VC = total variable cost;

Q = vector for hospital output;

P = vector for input price;

K = vector for fixed capital stock;

F = vector for other factors that affect the level of cost;

D = dummy which shift the level of intercepts;

ε = random disturbance; and

Other Greek letters = parameters.

The details of outputs (Q_i), prices (P_i), capital (K) and other variables (F_i, D_i) are explained in Section 3.5. Since there were no zero outputs included in the sampled hospitals, there was no need to employ the generalised translog form.

Two constraints on parameters were imposed on the TMCF model. First a symmetric restriction was imposed on to the coefficients whereby:

$$\beta_{tij} = \beta_{tji} \text{ (for all i, j)}, \gamma_{tij} = \gamma_{tji} \text{ (for all i, j); and} \tag{3-9}$$

$$\beta_{vij} = \beta_{vji} \text{ (for all i, j)}, \gamma_{vij} = \gamma_{vji} \text{ (for all i, j).} \tag{3-10}$$

Another constraint was imposed on the model in order to satisfy the precondition of linear homogeneity of degree one in input prices so that the dual relationships between the cost and transformation functions are preserved (i.e. if we double all input prices at once, it would lead to doubling of the cost):

$$\sum_i \gamma_{ti} = 1, \sum_i \gamma_{tij} = \sum_j \gamma_{tij} = \sum_i \delta_{tij} = 0\text{; and} \tag{3-11}$$

$$\sum_i \gamma_{vi} = 1, \sum_i \gamma_{vij} = \sum_j \gamma_{vij} = \sum_i \delta_{vij} = \sum_i \tau_{vi} = 0. \tag{3-12}$$

Other restrictions that are implicitly assumed for an ad hoc specification, such as linearity and separability of impacts of different variables on average cost, could be dispensed of.

One of the major drawbacks encountered with flexible functions is the large number of parameters to be estimated. OLS estimation may suffer from degrees of freedom and severe multicollinearity problems, which may lead to inefficient parameter estimations. This issue, however, could be handled within a systems framework by simultaneously estimating the cost function with the derived cost share equations via Shephard's lemma (Christensen & Greene 1975; Coelli *et al*. 1998), provided that the function is logarithmically differentiable with respect to each input price. The cost share equations took the form of

Long-run

$$S_{ti} = P_iX_i/TC = (\partial TC/\partial P_i)(P_i/TC) = \partial lnTC/\partial lnP_i$$
$$= \gamma_{ti} + \sum_{j=1}^{6}\gamma_{tij}lnP_j + \sum_{j=1}^{3}\delta_{tij}lnQ_j + \varepsilon_{ti} \quad (3\text{-}13)$$

Short-run

$$S_{vi} = P_iX_i/VC = (\partial VC/\partial P_i)(P_i/VC) = \partial lnVC/\partial lnP_i$$
$$= \gamma_{vi} + \sum_{j=1}^{5}\gamma_{vij}lnP_j + \sum_{j=1}^{3}\delta_{vij}lnQ_j + \tau_{vi}lnK + \varepsilon_{vi} \quad (3\text{-}14)$$

where S_i represents the cost share proportion of the i_{th} input factor, and X_i the quantity of the i_{th} input factor. Whilst some studies estimated the systems of equations by maximum likelihood method (Cowing & Holtman 1983; Alba 1995), Zellner's (1962) seemingly unrelated regressions (SUR), also called joint generalised least squares (JGLS), was used in this study. Since the sum of S_i equals to unity, one cost share equation was omitted to avoid the singularity of covariance matrix (Coelli *et al*. 1998). Christensen & Greene (1976), however, argued that the result of parameter estimation is not invariant to which cost share equation is omitted when SUR method is employed. This inconsistency, however, will be overcome by iterating the SUR estimation until the convergence is achieved (*ibid.*).

3.4.3 Models for unit cost estimation

Whilst the cost function discussed in Sub-section 3.4.2 is able to forecast the total cost or total variable cost of hospitals, they do not provide information on unit costs. The econometric estimation method, which is the focus of this study, attempts to simplify the accounting-based method (see Sub-section 3.4.1) to roughly estimate the unit costs. This issue requires additional information on the cost proportion of PS over total cost as well as unit cost ratio between inpatient and outpatient services to replace the procedure of the Steps 1−4 in the accounting-based method:

$$\frac{CPS}{TC} = A; \text{ and}$$

$$UCOP : UCIP = 1 : B \quad \leftrightarrow \quad \frac{UCOP}{UCIP} = \frac{1}{B} \qquad (3\text{-}15)$$

where CPS denotes the full cost of patient services, and UCOP and UCIP denote the unit costs of outpatient visit and inpatient admissios respectively. These proportions and ratios enable the estimation of both of the unit costs from the estimated total cost as follows:

$$UCIP = \frac{CPS}{\#\text{ of inpatient admissions} + (\#\text{ of outpatient visits})/B} \text{ ; and}$$

$$UCOP = \frac{CPS}{B(\#\text{ of inpatient admissions}) + \#\text{ of outpatient visits}} \qquad (3\text{-}16)$$

where CPS = TC x A.

Since, however, there were neither a theory on the regression form nor any theoretically identified determinant factors to estimate such a proportion and ratio, the specifications were adopted from the ones used in past studies. Whilst no literature reviewed in this study provided a model for the estimation of the proportion of CPS over TC, the WHO-CHOICE Project (Adam & Evans 2006) provided a model to estimate the unit cost ratio. Therefore the model used in that project was applied to both of the regressions of this study:

$$ln(\text{CPS/TC}) = \theta_0 + \sum_{k=1}^{3}\theta_k \, ln\text{Z}_k + \sum_{k=1}^{4}\psi_k\text{D}_k + \upsilon_c \quad (3\text{-}17)$$

$$ln(\text{UCOP/UCIP}) = \varsigma_0 + \sum_{k=1}^{3}\varsigma_k \, ln\text{Z}_k + \sum_{k=1}^{4}\rho_k\text{D}_k + \upsilon_u \quad (3\text{-}18)$$

where Z_k and D_k represent the explanatory variables, υ the random disturbance, and the Greek letters the parameters.

3.5 Variables and operational definitions

3.5.1 Variables for the cost function

The variables were identified alongside the model assumed for the cost function. The identified variables are listed in Tables 3-1 and 3-2.

Table 3-1: Variables for the long-run cost function

Category		Variable	
Dependent variable		TC	Total cost of hospital (THB)
Explanatory variables			
Outputs	Q_1	IPD	Number of inpatient admissions (#)
	Q_2	OPD	Number of outpatient visits (#)
	Q_3	LOS	Average length of stay of inpatients (#)
Inputs	P_1	MD	Average price of medical doctors (THB)
	P_2	RN	Average price of nurses (THB)
	P_3	MED	Average price of other medical staff (THB)
	P_4	NMED	Average price of non-medical staff (THB)
	P_5	MAT	Average price of materials per patient (THB)
	P_6	CAP	Average price of capital per bed (THB)
Additional factors	F_1	CM	Case mix index (average DRG-RW)
	F_2	IPUC	UC inpatient proportion (%)
	F_3	OPUC	UC outpatient proportion (%)
	$D_{1/2/3}$	$LOC_{1/2/3}$	Dummy location (Central – East/North/South)
	D_4	LEV	Dummy level of hospital (community – provincial)

Table 3-2: Variables for the short-run cost function

Category		Variable	
Dependent variable		VC	Total variable cost of hospital (THB)
Explanatory variables			
Outputs	Q_1	IPD	Number of inpatient admissions (#)
	Q_2	OPD	Number of outpatient visits (#)
	Q_3	LOS	Average length of stay of inpatients (#)
Inputs	P_1	MD	Average price of medical doctors (THB)
	P_2	RN	Average price of nurses (THB)
	P_3	MED	Average price of other medical staff (THB)
	P_4	NMED	Average price of non-medical staff (THB)
	P_5	MAT	Average price of materials per patient (THB)
	K	BED	Number of beds (#)
Additional factors	F_1	CM	Case mix index (average DRG-RW)
	F_2	IPUC	UC inpatient proportion (%)
	F_3	OPUC	UC outpatient proportion (%)
	$D_{1/2/3}$	$LOC_{1/2/3}$	Dummy location (Central – East/North/South)
	D_4	LEV	Dummy level of hospital (community – provincial)

Definitions of dependent variables

<u>TC: Total cost</u>

Total cost refers to all expenditures incurred in 2006 at the sampled hospitals. It includes all operational costs such as wages, utilities, drugs, foods, linens, and other consumables, as well as interest, loss of assets, and annual capital depreciations of buildings and equipment recorded in accounting books. Strictly speaking, however, "cost" in economic term implies the opportunity cost which is not recorded in the budgetary expenditure flows of public hospitals (e.g. additional income of hospital staff other than those appearing on the wage bills). Due to data limitations, even though the term "cost" is used throughout this paper, it should be interpreted as "public hospital expenditure".

VC: Total variable cost

Variable costs refer to those costs which are able to adjust depending on the level of outputs. In the short-run, there are certain fixed costs which cannot be adjusted according to output levels such as capital depreciation. However, the quantity and costs of drug, supplies, and labours can be adjusted, and hence there is a division between fixed and variable costs. In this study, the total variable cost is defined as the sum of labour cost and material cost (such as drug and supplies).

Definitions of explanatory variables: Outputs

All variables included in this category are expected to be positively correlated with hospital cost following the regularity conditions of duality theorem: non-decreasing left continuous function in outputs.

IPD (Q_1): Number of inpatient admissions

The inpatient service is the primary output of a hospital and consumes the largest portion of resources. It can be measured either by the number of bed-days or number of admissions (or discharges). The number of admissions in 2006 is used as the measure of inpatient quantity in this study, since most accounting-based cost analyses in Thailand use this measure.

OPD (Q_2): Number of outpatient visits

The outpatient service is another important output of a hospital. It is normally measured by the number of patient visits. Whilst some unit cost studies distinguished emergency services, dental services and other services from outpatient services, all of them are counted as outpatient visits in this study for simplification. The number of all outpatient visits in 2006 is used to measure the outpatient quantity.

LOS (Q_3): Average length of stay

Whilst there are two units of measures for inpatient services, namely inpatient bed-day and admission (or discharge), there has not been an agreement on any preference over the other. One way to overcome this dilemma is to include both output measures by using the number of admission as the main variable and the average length of stay to capture the bed-day characteristics as was suggested by Vita (1990). The average length of stay is calculated in the following manner:

$$\text{LOS} = \frac{\text{Number of inpatient bed-days in 2006}}{\text{Number of admissions in 2006}}.$$

Whilst Vita (*ibid.*) did not include the second order variables associated with length of stay in order to economise the number of parameters, they are included in this study since the number of parameters is still at a manageable level.

Definitions of explanatory variables: Input prices

All variables included in this category are expected to be positively correlated to total cost following the regularity conditions of duality theorem: non-decreasing function in input prices.

MD (P_1): Average price of medical doctors

This price is defined as the average salary and fringe benefits of all medical doctors at each hospital. Whilst the total amount of salary & fringe benefit for all staff was available for year 2006, its breakdown was not. On the other hand the detailed salaries for different staff categories were available for year 2008, but not the fringe benefit. Therefore the average price of medical doctors for year 2006 was derived in the following manner:

1) Average MD salary$_{2008}$ = $\frac{\Sigma(\text{Monthly salary of each medical doctor in 2008})}{\text{Number of medical doctors in 2008}}$

2) Scale back the average MD salary$_{2008}$ by 2.5 point[2] on the "Civil Servant Wage Scale" to approximate the average MD salary$_{2006}$

3) Average MD price$_{2006}$

$$= \text{Average MD salary}_{2006} \times \left(1 + \frac{\text{Total amount of fringe benefit for all staff in 2006}}{\text{Total amount of salary for all staff in 2006}}\right)$$

Since wages of public hospital staff are centrally standardised for each cadre/level in Thailand, there should be no variations among hospitals. However, the average wage may vary significantly among hospitals reflecting the skill mix and seniority of staff in the same cadre which is likely to affect the cost structure of hospitals.

RN (P_2): Average price of nurses

Generally the wages of nurse consume the largest portion of hospital costs. The price for year 2006 was derived in the same manner as that for the medical doctor. The same reason mentioned for MD variable justifies the inclusion of this variable in the function.

MED (P_3): Average price of other medical staff

This category includes all medical staff other than medical doctors and nurses such as dentists, pharmacists, physiotherapists, laboratory technician, radiologists etc. The price for year 2006 was derived in the same manner as for the medical doctor. The same reason mentioned for MD variable justifies the inclusion of this variable in the function.

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[2] Generally, a civil servant receives an increase of 1−1.5 points scale-up in wage every year, which results in 2−3 points scale-up in two years period. In this connection, the average scale-up of 2.5 points was assumed for the calculation.

NMED (P_4): Average price of non-medical staff

This category includes all non-medical staff members such as health promoter, administrator, accountant, registrar, technician, statistician, human resource officer etc. The price for year 2006 was derived in the same manner as for the medical doctor. The same reason mentioned for MD variable justifies the inclusion of this variable in the function.

MAT (P_5): Average price of material per patient

Materials include all other costs incurred other than those of labour and capital. It includes drug and medication, medical supplies, non-medical supplies, utilities etc. The value of materials as of year 2006 was derived in the following manner:

$$MAT = \frac{\text{Total Cost} - \text{Total Salary \& Fringe Benefit} - \text{Total Capital Cost}}{\text{Number of patients (\# inpatient admissions + \# outpatient visits)}} .$$

Per patient unit was used by Alba (1995) to obtain the price of drugs and medical supplies.

CAP (P_6): Average price of capital per bed

In the long-run cost function, capital is considered as variable cost which is assumed to be adjusted to the cost-minimising level. The value of capital expenditure is the total amount of depreciation incurred in a year. The capital price as of 2006 is calculated in the following manner:

$$CAP = \frac{\Sigma(\text{Depreciations of each capital in 2006})}{\text{Number of beds in 2006}} .$$

Per bed unit was used by Hadley & Swartz (1989) and Zuckerman *et al*. (1993) to obtain the price of capital.

Definitions of explanatory variables: Fixed input

BED (K): Number of beds

In the short-run cost function, capitals are considered fixed inputs which may not necessarily be adjusted to cost-minimising levels. The number of beds has been the most frequently used proxy to measure the fixed capital stock in a short-run hospital cost function (Vita 1990; Alba 1995; Aletras 1999).

Definitions of explanatory variables: Additional factors

CM (F_1): Case mix index

The average DRG-RW is used for this variable. The RW (relative weight) indicates the relative intensity of care for each category of DRG. Since DRG-RW is used as the base for prospective payment for each inpatient case under UC, it is included as a variable to capture the unit cost disparities among hospitals. It is assumed that higher values of CM reflect the higher complexity of cases, which have positive relationships with costs. CM is derived as follows:

$$CM = \frac{\Sigma(\text{RW of individual inpatient cases in 2006})}{\text{Total number of inpatient cases in 2006}}.$$

IPUC (F_2): % of UC inpatient cases among all inpatient cases

This variable is assumed to capture the cost containment/escalation behaviour of the hospital. Whilst the inpatient services are financed by DRG based prospective payment mechanism for UC patients, it is expected to affect the behaviours of doctors to contain treatments and costs. This variable is defined as follows:

$$IPUC = \frac{\text{Total number of UC inpatient admissions in 2006}}{\text{Total number of all inpatient admissions in 2006}} \times 100.$$

OPUC (F_3): % of UC outpatient cases among all outpatient cases

This variable is assumed to capture the cost containment/escalation behaviour of the hospital. Whilst the outpatient services are financed based on capitation for UC patients, it is expected to affect the behaviours of doctors to contain treatments and costs. This variable is defined as follows:

$$OPUC = \frac{\text{Total number of UC outpatient visits in 2006}}{\text{Total number of all outpatient visits in 2006}} \times 100 .$$

$LOC_{1/2/3}$ ($D_{1/2/3}$): Dummy location

This dummy variable is assumed to reflect the regional variations of price levels. Transportation cost for centrally purchased equipments and consumables may also affect the price levels in different regions. The meaning of each variable is defined as follows:

LOC_1: 1 = Eastern region 0 = otherwise

LOC_2: 1 = Northern region 0 = otherwise

LOC_3: 1 = Southern region 0 = otherwise

$LOC_1 = LOC_2 = LOC_3 = 0$: Central region

LEV (D_4): Dummy level of hospital

This dummy variable is assumed to reflect the different types/levels of cases the hospitals are caring. Provincial hospitals are expected to have lower unit costs compared to community hospitals referring to the study conducted by Supachutikul (1996). The meaning of this variable is defined as follows:

LEV: 1 = Provincial hospital

0 = Community hospital

3.5.2 Variables for unit cost estimation

The variables were identified alongside the models employed for unit cost estimations. The identified variables are listed in Tables 3-3 and 3-4.

Table 3-3: Variables for patient service cost estimation

Category		Variable	
Dependent variable		CPS/FC	Proportion of patient service cost over full cost
Explanatory variables	Z_1	BED	Number of beds (#)
	Z_2	OCP	Bed occupancy rate (proportion)
	Z_3	LOS	Average length of stay (#)
	$D_{1/2}$	$LEV_{1/2}$	Dummy level of hospital (community – provincial/regional)
	D_3	SIM	Dummy allocation method (step-down – simultaneous)
	D_4	CC	Dummy inclusion of capital cost (included – not included)

Table 3-4: Variables for unit cost estimation

Category		Variable	
Dependent variable		UCOP/UCIP	Ratio of outpatient unit cost over inpatient unit cost
Explanatory variables	Z_1	BED	Number of beds (#)
	Z_2	OCP	Bed occupancy rate (proportion)
	Z_3	LOS	Average length of stay (#)
	$D_{1/2}$	$LEV_{1/2}$	Dummy level of hospital (community – provincial/regional)
	D_3	SIM	Dummy allocation method (step-down – simultaneous)
	D_4	CC	Dummy inclusion of capital cost (included – not included)

CPS/FC: Proportion of patient service cost over full cost

Hospital cost can be divided into patient services (outpatient and inpatient services) and non-patient services (such as health promotion activities). These two cost centres include the overhead cost allocated from revenue-producing and non-revenue producing cost centres and hence can be used to calculate the final unit cost for each service. Since the patient service will be further divided into inpatient and outpatient services, the proportion of patient services over full cost (can be total cost or total variable cost, depending on the sample studies) must first be estimated.

UCOP/UCIP: Ratio of outpatient unit cost over inpatient unit cost

Unit costs of inpatient admission and outpatient visit are generally not routinely available among public hospitals. The unit costs used in this study are those derived from accounting-based studies in the past where the overhead costs are allocated by means of step-down, simultaneous, or double-distribution allocation methods depending on each study. For those studies where the outpatient unit costs were broken down to more specific categories, they were aggregated and recalculated to obtain a single outpatient unit cost for each hospital.

BED (Z_1): Number of beds

The number of beds reflects the capacity to accommodate inpatients and hence may affect the level of inpatient unit cost. This data, however, was not available for many sample hospitals. In such instances, the numbers of beds as of year 2006, which were collected for the cost function analysis, was used under the assumption that the size of the hospitals have not changed over years.

OCP (Z_2): Bed occupancy rate

Bed occupancy rate is associated with allocative efficiency of hospitals and would affect the unit cost of inpatient services. OCP is calculated in the following manner:

$$OCP = \frac{\text{Number of inpatient bed-days for a year}}{\text{Number of beds x 365 days per year}} .$$

LOS (Z_3): Average length of stay

The length of stay is a major component which affects the unit cost level of one inpatient admission. It is calculated in the same manner as the above LOS (Q_3).

LEV (D_1): Dummy level of hospital

This dummy variable is assumed to reflect the different types/severities of cases as well as different sizes of hospitals at each level. Provincial hospitals are expected to have lower unit costs compared to community hospitals referring to the study conducted by Supachutikul (1996). On the other hand, regional hospitals have significantly higher unit cost due to significant length of stay (*ibid.*). This variable is defined as follows:

LEV_1: 1 = Provincial hospital 0 = otherwise

LEV_2: 1 = Regional hospital 0 = otherwise

$LEV_1 = LEV_2 = 0$: Community hospital

SIM (D_2): Dummy overhead allocation method

Whilst there are two frequently used methods for overhead cost allocation, namely step-down allocation and simultaneous allocation, the estimated results may differ. In order to account for such differences, a dummy is included to distinguish the study results. Since double-distribution method was used in only one study, it was included in the simultaneous method.

SIM: 1 = Simultaneous

0 = Step-down

CC (D_3): Dummy inclusion of capital cost in the analysis

More than half of the sampled hospitals did not include the capital cost in their analyses. Therefore the unit costs calculated in such studies reflect the variable unit cost of services and hence is distinguished from full unit cost. Such samples were not excluded to maintain the already small sample size.

CC: 1 = not including capital costs

0 = including capital costs

3.6 Functional specifications

Cost function and cost share equations

<u>Long-run cost function</u>

$$
\begin{aligned}
\textit{ln}\text{TC} = {} & \alpha_0 + \beta_1 \textit{ln}\text{IPD} + \beta_2 \textit{ln}\text{OPD} + \beta_3 \textit{ln}\text{LOS} \\
& + 1/2\beta_{11}(\textit{ln}\text{IPD})^2 + 1/2\beta_{22}(\textit{ln}\text{OPD})^2 + 1/2\beta_{33}(\textit{ln}\text{LOS})^2 \\
& + \beta_{12}\textit{ln}\text{IPD}\textit{ln}\text{OPD} + \beta_{13}\textit{ln}\text{IPD}\textit{ln}\text{LOS} + \beta_{23}\textit{ln}\text{OPD}\textit{ln}\text{LOS} \\
& + \gamma_1\textit{ln}\text{MD} + \gamma_2\textit{ln}\text{RN} + \gamma_3\textit{ln}\text{MED} + \gamma_4\textit{ln}\text{NMED} + \gamma_5\textit{ln}\text{MAT} + \gamma_6\textit{ln}\text{CAP} \\
& + 1/2\gamma_{11}(\textit{ln}\text{MD})^2 + 1/2\gamma_{22}(\textit{ln}\text{RN})^2 + 1/2\gamma_{33}(\textit{ln}\text{MED})^2 \\
& + 1/2\gamma_{44}(\textit{ln}\text{NMED})^2 + 1/2\gamma_{55}(\textit{ln}\text{MAT})^2 + 1/2\gamma_{66}(\textit{ln}\text{CAP})^2 \\
& + \gamma_{12}\textit{ln}\text{MD}\textit{ln}\text{RN} + \gamma_{13}\textit{ln}\text{MD}\textit{ln}\text{MED} + \gamma_{14}\textit{ln}\text{MD}\textit{ln}\text{NMED} \\
& + \gamma_{15}\textit{ln}\text{MD}\textit{ln}\text{MAT} + \gamma_{16}\textit{ln}\text{MD}\textit{ln}\text{CAP} + \gamma_{23}\textit{ln}\text{RN}\textit{ln}\text{MED} \\
& + \gamma_{24}\textit{ln}\text{RN}\textit{ln}\text{NMED} + \gamma_{25}\textit{ln}\text{RN}\textit{ln}\text{MAT} + \gamma_{26}\textit{ln}\text{RN}\textit{ln}\text{CAP} \\
& + \gamma_{34}\textit{ln}\text{MED}\textit{ln}\text{NMED} + \gamma_{35}\textit{ln}\text{MED}\textit{ln}\text{MAT} + \gamma_{36}\textit{ln}\text{MED}\textit{ln}\text{CAP} \\
& + \gamma_{45}\textit{ln}\text{NMED}\textit{ln}\text{MAT} + \gamma_{46}\textit{ln}\text{NMED}\textit{ln}\text{CAP} + \gamma_{56}\textit{ln}\text{MAT}\textit{ln}\text{CAP} \\
& + \delta_{11}\textit{ln}\text{MD}\textit{ln}\text{IPD} + \delta_{12}\textit{ln}\text{MD}\textit{ln}\text{OPD} + \delta_{13}\textit{ln}\text{MD}\textit{ln}\text{LOS} \\
& + \delta_{21}\textit{ln}\text{RN}\textit{ln}\text{IPD} + \delta_{22}\textit{ln}\text{RN}\textit{ln}\text{OPD} + \delta_{23}\textit{ln}\text{RN}\textit{ln}\text{LOS} \\
& + \delta_{31}\textit{ln}\text{MED}\textit{ln}\text{IPD} + \delta_{32}\textit{ln}\text{MED}\textit{ln}\text{OPD} + \delta_{33}\textit{ln}\text{MED}\textit{ln}\text{LOS} \\
& + \delta_{41}\textit{ln}\text{NMED}\textit{ln}\text{IPD} + \delta_{42}\textit{ln}\text{NMED}\textit{ln}\text{OPD} + \delta_{43}\textit{ln}\text{NMED}\textit{ln}\text{LOS} \\
& + \delta_{51}\textit{ln}\text{MAT}\textit{ln}\text{IPD} + \delta_{52}\textit{ln}\text{MAT}\textit{ln}\text{OPD} + \delta_{53}\textit{ln}\text{MAT}\textit{ln}\text{LOS} \\
& + \delta_{61}\textit{ln}\text{CAP}\textit{ln}\text{IPD} + \delta_{62}\textit{ln}\text{CAP}\textit{ln}\text{OPD} + \delta_{63}\textit{ln}\text{CAP}\textit{ln}\text{LOS} \\
& + \eta_1\text{CM} + \eta_2\text{IPUC} + \eta_3\text{OPUC} + \varphi_1\text{LOC}_1 + \varphi_2\text{LOC}_2 + \varphi_3\text{LOC}_3 + \varphi_4\text{LEV} + \varepsilon
\end{aligned}
\tag{3-19}
$$

The derived cost share equations from the above total cost function are described as follows:

$$\begin{aligned}
SMD &= \partial lnTC/\partial lnMD \\
&= \gamma_1 + \gamma_{11}lnMD + \gamma_{12}lnRN + \gamma_{13}lnMED + \gamma_{14}lnNMED + \gamma_{15}lnMAT \\
&\quad + \gamma_{16}lnCAP + \delta_{11}lnIPD + \delta_{12}lnOPD + \delta_{13}lnLOS + \varepsilon_1
\end{aligned}$$

$$\begin{aligned}
SRN &= \partial lnTC/\partial lnRN \\
&= \gamma_2 + \gamma_{22}lnRN + \gamma_{12}lnMD + \gamma_{23}lnMED + \gamma_{24}lnNMED + \gamma_{25}lnMAT \\
&\quad + \gamma_{26}lnCAP + \delta_{21}lnIPD + \delta_{22}lnOPD + \delta_{23}lnLOS + \varepsilon_2
\end{aligned}$$

$$\begin{aligned}
SMED &= \partial lnTC/\partial lnMED \\
&= \gamma_3 + \gamma_{33}lnMED + \gamma_{13}lnMD + \gamma_{23}lnRN + \gamma_{34}lnNMED + \gamma_{35}lnMAT \\
&\quad + \gamma_{36}lnCAP + \delta_{31}lnIPD + \delta_{32}lnOPD + \delta_{33}lnLOS + \varepsilon_3
\end{aligned}$$

$$\begin{aligned}
SNMED &= \partial lnTC/\partial lnNMED \\
&= \gamma_4 + \gamma_{44}lnNMED + \gamma_{14}lnMD + \gamma_{24}lnRN + \gamma_{34}lnMED + \gamma_{45}lnMAT \\
&\quad + \gamma_{46}lnCAP + \delta_{41}lnIPD + \delta_{42}lnOPD + \delta_{43}lnLOS + \varepsilon_4
\end{aligned}$$

$$\begin{aligned}
SMAT &= \partial lnTC/\partial lnMAT \\
&= \gamma_5 + \gamma_{55}lnMAT + \gamma_{15}lnMD + \gamma_{25}lnRN + \gamma_{35}lnMED + \gamma_{45}lnNMED \\
&\quad + \gamma_{56}lnCAP + \delta_{51}lnIPD + \delta_{52}lnOPD + \delta_{53}lnLOS + \varepsilon_5
\end{aligned}$$

$$\begin{aligned}
SCAP &= \partial lnTC/\partial lnCAP \\
&= \gamma_6 + \gamma_{66}lnCAP + \gamma_{16}lnMD + \gamma_{26}lnRN + \gamma_{36}lnMED + \gamma_{46}lnNMED \\
&\quad + \gamma_{56}lnMAT + \delta_{61}lnIPD + \delta_{62}lnOPD + \delta_{63}lnLOS + \varepsilon_6 \qquad (3\text{-}20)
\end{aligned}$$

The constraints imposed on the above cost function and cost share equations are described in Table 3-5.

Table 3-5: Impositions of constraints (long-run)

Constraints	Impositions[3]
$\sum_i \gamma_i = 1$	$\gamma_5 = 1-\gamma_1-\gamma_2-\gamma_3-\gamma_4-\gamma_6$
$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$	$\gamma_{15} = 0-\gamma_{11}-\gamma_{12}-\gamma_{13}-\gamma_{14}-\gamma_{16}$ $\gamma_{25} = 0-\gamma_{12}-\gamma_{22}-\gamma_{23}-\gamma_{24}-\gamma_{26}$ $\gamma_{35} = 0-\gamma_{13}-\gamma_{23}-\gamma_{33}-\gamma_{34}-\gamma_{36}$ $\gamma_{45} = 0-\gamma_{14}-\gamma_{24}-\gamma_{34}-\gamma_{44}-\gamma_{46}$ $\gamma_{55} = 0-(0-\gamma_{11}-\gamma_{12}-\gamma_{13}-\gamma_{14}-\gamma_{16})$ $-(0-\gamma_{12}-\gamma_{22}-\gamma_{23}-\gamma_{24}-\gamma_{26})$ $-(0-\gamma_{13}-\gamma_{23}-\gamma_{33}-\gamma_{34}-\gamma_{36})$ $-(0-\gamma_{14}-\gamma_{24}-\gamma_{34}-\gamma_{44}-\gamma_{46})$ $-(0-\gamma_{16}-\gamma_{26}-\gamma_{36}-\gamma_{46}-\gamma_{56})$ $\gamma_{56} = 0-\gamma_{16}-\gamma_{26}-\gamma_{36}-\gamma_{46}-\gamma_{56}$
$\sum_i \delta_{ij} = 0$	$\delta_{51} = 0-\delta_{11}-\delta_{21}-\delta_{31}-\delta_{41}-\delta_{61}$ $\delta_{52} = 0-\delta_{12}-\delta_{22}-\delta_{32}-\delta_{42}-\delta_{62}$ $\delta_{53} = 0-\delta_{13}-\delta_{23}-\delta_{33}-\delta_{43}-\delta_{63}$

<u>Short-run cost function</u>

$$
\begin{aligned}
\mathit{ln}VC = {} & \alpha_0 + \beta_1 \mathit{ln}IPD + \beta_2 \mathit{ln}OPD + \beta_3 \mathit{ln}LOS \\
& + 1/2\beta_{11}(\mathit{ln}IPD)^2 + 1/2\beta_{22}(\mathit{ln}OPD)^2 + 1/2\beta_{33}(\mathit{ln}LOS)^2 \\
& + \beta_{12}\mathit{ln}IPD\mathit{ln}OPD + \beta_{13}\mathit{ln}IPD\mathit{ln}LOS + \beta_{23}\mathit{ln}OPD\mathit{ln}LOS \\
& + \gamma_1 \mathit{ln}MD + \gamma_2 \mathit{ln}RN + \gamma_3 \mathit{ln}MED + \gamma_4 \mathit{ln}NMED + \gamma_5 \mathit{ln}MAT \\
& + 1/2\gamma_{11}(\mathit{ln}MD)^2 + 1/2\gamma_{22}(\mathit{ln}RN)^2 + 1/2\gamma_{33}(\mathit{ln}MED)^2 \\
& + 1/2\gamma_{44}(\mathit{ln}NMED)^2 + 1/2\gamma_{55}(\mathit{ln}MAT)^2 \\
& + \gamma_{12}\mathit{ln}MD\mathit{ln}RN + \gamma_{13}\mathit{ln}MD\mathit{ln}MED + \gamma_{14}\mathit{ln}MD\mathit{ln}NMED + \gamma_{15}\mathit{ln}MD\mathit{ln}MAT \\
& + \gamma_{23}\mathit{ln}RN\mathit{ln}MED + \gamma_{24}\mathit{ln}RN\mathit{ln}NMED + \gamma_{25}\mathit{ln}RN\mathit{ln}MAT + \gamma_{34}\mathit{ln}MED\mathit{ln}NMED \\
& + \gamma_{35}\mathit{ln}MED\mathit{ln}MAT + \gamma_{45}\mathit{ln}NMED\mathit{ln}MAT \\
& + \delta_{11}\mathit{ln}MD\mathit{ln}IPD + \delta_{12}\mathit{ln}MD\mathit{ln}OPD + \delta_{13}\mathit{ln}MD\mathit{ln}LOS
\end{aligned}
$$

[3] In order to fully recover the information of the imposed parameters, two alternative regressions were run by imposing the constraints on $\gamma_2, \gamma_{12}, \gamma_{22}, \gamma_{23}, \gamma_{24}, \gamma_{25}, \gamma_{26}, \delta_{21}, \delta_{22}, \delta_{23}$, and $\gamma_4, \gamma_{14}, \gamma_{24}, \gamma_{34}, \gamma_{44}, \gamma_{45}, \gamma_{46}, \delta_{41}, \delta_{42}, \delta_{43}$.

$$+ \delta_{21} ln\text{RN} ln\text{IPD} + \delta_{22} ln\text{RN} ln\text{OPD} + \delta_{23} ln\text{RN} ln\text{LOS}$$

$$+ \delta_{31} ln\text{MED} ln\text{IPD} + \delta_{32} ln\text{MED} ln\text{OPD} + \delta_{33} ln\text{MED} ln\text{LOS}$$

$$+ \delta_{41} ln\text{NMED} ln\text{IPD} + \delta_{42} ln\text{NMED} ln\text{OPD} + \delta_{43} ln\text{NMED} ln\text{LOS}$$

$$+ \delta_{51} ln\text{MAT} ln\text{IPD} + \delta_{52} ln\text{MAT} ln\text{OPD} + \delta_{53} ln\text{MAT} ln\text{LOS}$$

$$+ \kappa_1 ln\text{BED} + 1/2\kappa_{11}(ln\text{BED})^2 + \tau_{11} ln\text{MD} ln\text{BED} + \tau_{21} ln\text{RN} ln\text{BED}$$

$$+ \tau_{31} ln\text{MED} ln\text{BED} + \tau_{41} ln\text{NMED} ln\text{BED} + \tau_{51} ln\text{MAT} ln\text{BED}$$

$$+ \pi_{11} ln\text{IPD} ln\text{BED} + \pi_{21} ln\text{OPD} ln\text{BED} + \pi_{31} ln\text{LOS} ln\text{BED}$$

$$+\eta_1\text{CM} +\eta_2\text{IPUC} + \eta_3\text{OPUC} + \varphi_1\text{LOC}_1 +\varphi_2\text{LOC}_2 +\varphi_3\text{LOC}_3 +\varphi_4\text{LEV} + \varepsilon$$

(3-21)

The derived cost share equations from the above variable cost function are described as follows:

$$\text{SMD} = \partial ln\text{VC}/\partial ln\text{MD}$$

$$= \gamma_1 + \gamma_{11} ln\text{MD} + \gamma_{12} ln\text{RN} + \gamma_{13} ln\text{MED} + \gamma_{14} ln\text{NMED} + \gamma_{15} ln\text{MAT}$$

$$+ \delta_{11} ln\text{IPD} + \delta_{12} ln\text{OPD} + \delta_{13} ln\text{LOS} + \tau_{11} ln\text{BED} + \varepsilon_1$$

$$\text{SRN} = \partial ln\text{VC}/\partial ln\text{RN}$$

$$= \gamma_2 + \gamma_{22} ln\text{RN} + \gamma_{12} ln\text{MD} + \gamma_{23} ln\text{MED} + \gamma_{24} ln\text{NMED} + \gamma_{25} ln\text{MAT}$$

$$+ \delta_{21} ln\text{IPD} + \delta_{22} ln\text{OPD} + \delta_{23} ln\text{LOS} + \tau_{21} ln\text{BED} + \varepsilon_2$$

$$\text{SMED} = \partial ln\text{VC}/\partial ln\text{MED}$$

$$= \gamma_3 + \gamma_{33} ln\text{MED} + \gamma_{13} ln\text{MD} + \gamma_{23} ln\text{RN} + \gamma_{34} ln\text{NMED} + \gamma_{35} ln\text{MAT}$$

$$+ \delta_{31} ln\text{IPD} + \delta_{32} ln\text{OPD} + \delta_{33} ln\text{LOS} + \tau_{31} ln\text{BED} + \varepsilon_3$$

$$\text{SNMED} = \partial ln\text{VC}/\partial ln\text{NMED}$$

$$= \gamma_4 + \gamma_{44} ln\text{NMED} + \gamma_{14} ln\text{MD} + \gamma_{24} ln\text{RN} + \gamma_{34} ln\text{MED} + \gamma_{45} ln\text{MAT}$$

$$+ \delta_{41} ln\text{IPD} + \delta_{42} ln\text{OPD} + \delta_{43} ln\text{LOS} + \tau_{41} ln\text{BED} + \varepsilon_4$$

SMAT = $\partial ln\text{VC}/\partial ln\text{MAT}$

$$= \gamma_5 + \gamma_{55}ln\text{MAT} + \gamma_{15}ln\text{MD} + \gamma_{25}ln\text{RN} + \gamma_{35}ln\text{MED} + \gamma_{45}ln\text{NMED}$$

$$+ \delta_{51}ln\text{IPD} + \delta_{52}ln\text{OPD} + \delta_{53}ln\text{LOS} + \tau_{51}ln\text{BED} + \varepsilon_5 \quad (3\text{-}22)$$

The constraints imposed on the above cost function and cost share equations are described in Table 3-6.

Table 3-6: Impositions of constraints (short-run)

Constraints	Impositions[4]
$\sum_i \gamma_i = 1$	$\gamma_5 = 1-\gamma_1-\gamma_2-\gamma_3-\gamma_4$
$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$	$\gamma_{15} = 0-\gamma_{11}-\gamma_{12}-\gamma_{13}-\gamma_{14}$ $\gamma_{25} = 0-\gamma_{12}-\gamma_{22}-\gamma_{23}-\gamma_{24}$ $\gamma_{35} = 0-\gamma_{13}-\gamma_{23}-\gamma_{33}-\gamma_{34}$ $\gamma_{45} = 0-\gamma_{14}-\gamma_{24}-\gamma_{34}-\gamma_{44}$ $\gamma_{55} = 0-(0-\gamma_{11}-\gamma_{12}-\gamma_{13}-\gamma_{14})$ $-(0-\gamma_{12}-\gamma_{22}-\gamma_{23}-\gamma_{24})$ $-(0-\gamma_{13}-\gamma_{23}-\gamma_{33}-\gamma_{34})$ $-(0-\gamma_{14}-\gamma_{24}-\gamma_{34}-\gamma_{44})$
$\sum_i \delta_{ij} = 0$	$\delta_{51} = 0-\delta_{11}-\delta_{21}-\delta_{31}-\delta_{41}$ $\delta_{52} = 0-\delta_{12}-\delta_{22}-\delta_{32}-\delta_{42}$ $\delta_{53} = 0-\delta_{13}-\delta_{23}-\delta_{33}-\delta_{43}$
$\sum_i \tau_{i1} = 0$	$\tau_{51} = 0-\tau_{11}-\tau_{21}-\tau_{31}-\tau_{41}$

Unit cost estimation

<u>Cost proportion of patient services estimation</u>

$$ln(\text{CPS/TC}) = \theta_0 + \theta_1 ln\text{BED} + \theta_2 ln\text{OCP} + \theta_3 ln\text{LOS} + \psi_1\text{LEV}_1 + \psi_2\text{LEV}_2 + \psi_3\text{SIM} + \psi_4\text{CC} + \upsilon_p \quad (3\text{-}23)$$

[4] In order to fully recover the information of the imposed parameters, two alternative regressions were run by imposing the constraints on $\gamma_2, \gamma_{12}, \gamma_{22}, \gamma_{32}, \gamma_{42}, \gamma_{52}, \delta_{21}, \delta_{22}, \delta_{23}, \tau_{21}$ and $\gamma_4, \gamma_{14}, \gamma_{24}, \gamma_{34}, \gamma_{44}, \gamma_{54}, \delta_{41}, \delta_{42}, \delta_{43}, \tau_{41}$.

<u>Unit cost ratio estimation</u>

$$ln(UCOP/UCIP) = \varsigma_0 + \varsigma_1 lnBED + \varsigma_2 lnOCP + \varsigma_3 lnLOS + \rho_1 LEV_1 + \rho_2 LEV_2 + \rho_3 SIM + \rho_4 CC + \upsilon_u \quad (3\text{-}24)$$

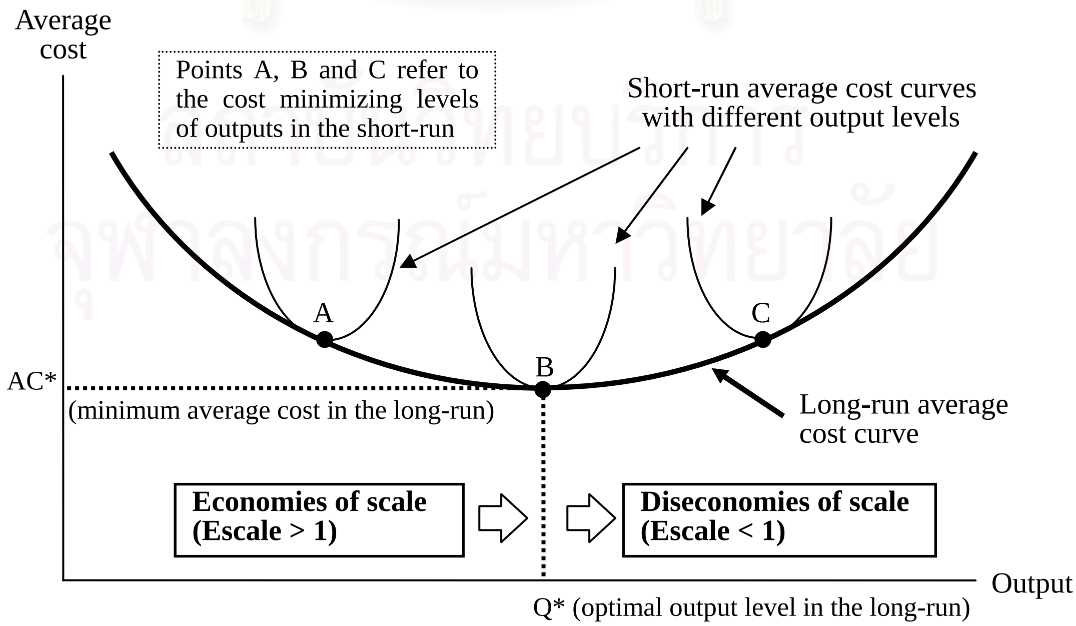
3.7 Economies of scale & scope

Once the parameters of the cost function have been estimated, economies of scale and scope were computed by using the mean values of the sample hospitals for each variable.

3.7.1 Economies of scale

Economies of scale refers to the notion that the long-run average cost faced by a firm will decline with respect to the increase of output levels of the same firm. This concept posits a health policy question whether small-sized hospitals should be merged to a large-sized hospital in order to gain efficiency improvements. The concept is graphically illustrated in Figure 3-5.

Figure 3-5: Average cost curves and Economies of scale



Ray economies of scale is said to exist when the reciprocal of sum of the cost elasticities with respect to output Q_i is (Wagstaff & Barnum 1992)

$$EScale = 1/\sum TCE_i = 1/\sum[(\partial TC/TC)/(\partial Q_i/Q_i)] = 1/\sum(\partial lnTC/\partial lnQ_i) \quad (3\text{-}25)$$

$$> 1$$

and diseconomies of scale if

$$EScale < 1.$$

This method, however, applies to a long-run cost function where the capital is assumed to be at the cost-minimising level. If this is applied to a short-run variable cost function, such was the case with Cowing & Holtman (1983), the findings do not provide information on the true scale economies (Vita 1990). There are two methods to account for this issue. The first one, which is theoretically more appealing, is to derive the long-run cost function from short-run by applying the envelopment condition where $\partial VC/\partial K = -r$ (*ibid.*; Aletras 1999). The optimal level of capital K* can be solved by applying the estimated parameters for the short-run variable cost function and taking the price of capital inputs. The long-run total cost function can then be derived by substituting the K with K* of Expression 3-5:

$$TC = VC + FC = f(w_1,w_2,K^*) + rK^*. \quad (3\text{-}26)$$

The formula for computing the scale economies in this case is given by Braeutigam & Daughety (1983, cited in Vita 1990):

$$EScale = \frac{1 - \partial lnVC/\partial lnK^*}{\sum(\partial lnVC/\partial lnQ_i)} \quad . \quad (3\text{-}27)$$

This method, however, requires accurate information on the price of capital and hence has generally not been used in empirical studies in the health sector (Aletras 1999). An alternative approach has normally been taken where K* is replaced by the actual amount of K in the above formula:

$$\text{EScale} = \frac{1 - \partial ln\text{VC}/\partial ln\text{K}}{\sum(\partial ln\text{VC}/\partial ln\text{Q}_i)} \quad . \tag{3-28}$$

This method, however, will not produce the same estimates as the first alternative. Whilst the first method will yield the scale economies along the efficient expansion path of the production function, the second method reflect the actual points of production. Braeutigam & Daughety (1983, cited in Vita 1990) argues that the first model is favoured if the firm is able to adjust the capital quickly, whilst the second would be superior if this is not the case.

3.7.2 Economies of scope

Economies of scope refers to the notion that the average cost of a firm reduces if several outputs are produced jointly rather than separately. It may occur in multi-product situations where hospitals typically apply. Economies of scope is said to exist if (Wagstaff & Barnum 1992)

$$\text{EScope} = \frac{(Q_1,0,..,0) + C(0,Q_2,..,0) + \ldots + C(0,0,..,Q_n)}{C(Q_1,Q_2,..,Q_n)} - 1 \tag{3-29}$$

$$> 0$$

and diseconomies of scope if

$$\text{EScope} < 0.$$

This method, however, may be faced with problems for a translog cost function which is a local approximation in the vicinity of the mean values (output etc.). Setting the output levels to zero, which is significantly apart from the approximation point, will result in an imprecise cost estimation which may severely distort the findings of scope economies. Therefore an alternative method has been suggested to estimate scope economies for a translog function by examining the weak cost complementarities (WCC) at the average point. Baumol *et al.* (1981, pp.74−75) defines that "the presence of weak cost complementarities implies that the marginal cost of producing any one product decreases (weakly) with the increases in the quantity of all other products". WCC is said to exist if

$$C_{ij} = \partial^2 C/\partial Q_i \partial Q_j \quad \text{(for all } i \neq j) \tag{3-30}$$

is negative for a long-run total cost function. This can be decomposed for a short-run total cost function (Cowing & Holtman 1983; Vita 1990; Alba 1996):

$$C_{Sij} = \partial^2 C/\partial Q_i \partial Q_j = \partial^2 VC/\partial Q_i \partial Q_j + (\partial^2 VC/\partial Q_j \partial K)(\partial K^*/\partial Q_j) \qquad \text{(for all } i \neq j). \tag{3-31}$$

Whilst deriving the function for K* is problematic due to the difficulties in obtaining a precise price information of capital, it is customary to assume the signs for $\partial K^*/\partial Q_j$ to be positive[5] and hence evaluate C_{Sij} based on the signs for $\partial^2 VC/\partial Q_i \partial Q_j$ and $\partial^2 VC/\partial Q_j \partial K$. In order for C_{Sij} to have a negative sign (existence of economies of scope), the sufficient condition is to have negative signs on both of them. A necessary condition for scope economy is to have at least one negative sign on either of them. It is known that $\partial^2 VC/\partial Q_i \partial Q_j$ is equivalent to $\beta_i \beta_j + \beta_{ij}$ ($i \neq j$, for all β) (Denny & Pinto 1978) and $\partial^2 VC/\partial Q_j \partial K$ to π_j where the Greek letters are the estimated parameters of a translog cost function, and so these parameters are to be used for evaluating economies of scope.

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5 It implies that K is a normal good, which is a reasonable assumption (see Siberberg 1978 pp.196−198).

3.8 Data processing and analysis

Since the cost function model employed in this analysis is linear in parameters (yet non-linear in variables), OLS method was able to be used to regress the data. However, as has been discussed in Sub-section 3.4.2, the perceived multicollinearity problem favoured the estimation of system of equations by Iterative SUR to improve efficiency of parameter estimation. On the other hand, the unit cost ratio was estimated using OLS since the number of parameters was sufficiently small.

CHAPTER IV

RESULTS AND DISCUSSION

In the previous Chapter, the models for the translog cost function and the unit cost ratio estimation were developed. The hypothetical explanatory variables have been identified and elaborated for each model employed in this study. This Chapter provides the results of regression analyses in the following five parts:

1. Descriptive analysis of the sampled hospitals ;
2. Empirical results of the estimated cost function;
3. Empirical results of the estimated unit cost ratio estimation models;
4. Cost simulations; and
5. Analyses of economies of scale & scope.

4.1 Descriptive analysis

4.1.1 Descriptive analysis of samples for the cost function

This study obtained the sample data from MOPH as of year 2006. Whilst all public community and provincial hospitals are the study population, some hospitals were not included due to data limitations. Out of 76 provinces in Thailand, data were available from 69 provinces. The seven provinces from which data were not available include: Samut Songkhram; Yasothon; Loei; Mukdahan; Lampang; and Bangkok Metropolis. Table 4-1 presents the distribution of the sampled hospitals in this study according to levels and regions. The sampled hospitals seem to be fairly well represented from all the regions.

Table 4-1: Number of sampled hospitals from each region

Hospital		Region				Total
Level	# Bed	Central	East	North	South	
Community	1−20	16	8	7	13	44
	21−30	69	127	75	66	337
	31−60	44	50	35	23	152
	61−90	11	25	11	5	52
	91−	10	11	5	3	29
	Sub-total	**150**	**221**	**133**	**110**	**614**
Provincial	1−200	2	0	1	5	8
	201−400	18	8	8	6	40
	401−600	11	4	7	5	27
	601−	4	5	4	2	15
	Sub-total	**35**	**17**	**20**	**18**	**90**
Total		**185**	**238**	**153**	**128**	**704**

The descriptive statistics of the variables used to estimate the cost function, including the sample means, standard deviations, maximum and minimum values are provided in Tables 4-2, 4-3, and 4-4.

Table 4-2: Descriptive statistics: cost function variables (all sample hospitals)

Variables	Mean Value	Std. Dev.	Minimum	Maximum
(Dependent variables)				
TC	155,764,355	283,000,000	10,007,350	2,497,953,029
VC	147,329,237	268,337,078	9,435,880	2,378,557,405
(Explanatory variables)				
IPD	7,490	10,325	408	78,634
OPD	112,261	102,190	12,054	728,862
LOS	3.26	0.96	1.67	11.77
MD	20,439	5,490	10,661	55,568
RN	20,491	2,385	12,115	28,212
MED	18,012	2,306	12,133	24,654
NMED	20,862	3,302	10,490	34,955
MAT	490	356	52	3,485
CAP	96,672	96,463	5,453	1,469,733
BED	94	151	10	1,019
CM	0.657	0.149	0.305	1.496
IPUC	76.62	10.82	35.01	95.34
OPUC	72.34	13.36	16.52	97.52
(Cost shares: long-run)				
SMD	0.03051	0.01391	0.00534	0.09365
SRN	0.29617	0.06180	0.11256	0.46440
SMED	0.10737	0.03477	0.02653	0.33909
SNMED	0.02839	0.01257	0.00448	0.11380
SMAT	0.47934	0.09953	0.16349	0.80750
SCAP	0.05822	0.04069	0.00473	0.43605
(Cost shares: short-run)				
SMD	0.03252	0.01518	0.00568	0.10356
SRN	0.31505	0.06697	0.11633	0.52152
SMED	0.11429	0.03792	0.02742	0.37378
SNMED	0.03027	0.01375	0.00469	0.12544
SMAT	0.50787	0.09844	0.22423	0.83453

N = 704

Table 4-3: Descriptive statistics: cost function variables (by hospital levels)

Variables	Community hospitals (N = 614)		Provincial hospitals (N = 90)	
	Mean Value	Std. Dev.	Mean Value	Std. Dev.
(Dependent variables)				
TC	69,022,947	41,096,063	747,533,513	465,604,305
VC	65,489,491	39,867,425	705,658,175	443,135,320
(Explanatory variables)				
IPD	4,366	2,971	28,800	15,960
OPD	82,975	42,920	312,051	153,354
LOS	3.02	0.71	4.92	0.85
MD	19,638	5,291	25,899	3,262
RN	20,338	2,427	21,540	1,750
MED	17,719	2,225	20,006	1,818
NMED	20,908	3,435	20,547	2,180
MAT	387	174	1,193	471
CAP	96,049	98,949	100,917	77,736
BED	44	27	432	207
CM	0.615	0.084	0.948	0.172
IPUC	78.20	10.00	65.83	10.06
OPUC	74.74	11.97	55.96	10.55
(Cost shares: long-run)				
SMD	0.02917	0.01374	0.03964	0.01153
SRN	0.30043	0.06210	0.26709	0.05122
SMED	0.11383	0.03208	0.06326	0.01436
SNMED	0.02940	0.01289	0.02154	0.00695
SMAT	0.46969	0.09861	0.54514	0.07901
SCAP	0.05748	0.03887	0.06333	0.05137
(Cost shares: short-run)				
SMD	0.03104	0.01487	0.04259	0.01342
SRN	0.31938	0.06759	0.28547	0.05424
SMED	0.12112	0.03533	0.06775	0.01581
SNMED	0.03132	0.01412	0.02313	0.00784
SMAT	0.49714	0.09724	0.58106	0.07216

Table 4-4: Descriptive statistics: cost function variables (by region & hospital levels)

Community hospitals

Variables	Mean Value			
	Central (N = 150)	East (N = 221)	North (N = 133)	South (N = 110)
(Dependent variables)				
TC	71,247,473	68,814,660	71,881,553	62,951,657
VC	67,767,576	65,315,441	68,481,731	59,114,802
(Explanatory variables)				
IPD	4,066	4,958	4,082	3,928
OPD	86,728	86,233	82,867	71,445
LOS	3.16	2.90	3.26	2.78
MD	20,110	19,687	19,348	19,248
RN	19,896	20,529	20,341	20,553
MED	17,404	17,335	18,187	18,357
NMED	20,517	21,143	20,778	21,128
MAT	390	374	413	378
CAP	99,285	89,207	86,751	116,626
BED	46	47	44	38
CM	0.613	0.627	0.649	0.549
IPUC	69.37	82.59	80.01	79.21
OPUC	62.05	81.38	78.34	74.36

Provincial hospitals

Variables	Mean Value			
	Central (N = 35)	East (N = 17)	North (N = 20)	South (N = 18)
(Dependent variables)				
TC	710,645,836	895,452,017	744,905,898	682,478,314
VC	667,575,096	851,324,869	702,982,713	645,107,242
(Explanatory variables)				
IPD	24,123	40,199	29,963	25,837
OPD	313,572	324,389	321,813	286,596
LOS	5.32	4.24	5.10	4.56
MD	26,470	25,521	25,602	25,473
RN	21,541	21,117	21,188	22,329
MED	20,064	19,697	19,725	20,499
NMED	20,693	20,517	20,209	20,669
MAT	1,133	1,297	1,222	1,178
CAP	106,256	80,337	90,931	121,069
BED	407	520	453	377
CM	0.949	1.022	0.987	0.832
IPUC	60.96	73.49	69.96	63.47
OPUC	50.16	64.23	58.52	56.59

4.1.2 Descriptive analysis of samples for unit cost estimation

This study obtained the sample data from various studies conducted in the past which ranges between 1998–2003[1]. The provinces included in this study are: Nonthhaburi; Pathum Thani; Samut Prakan; Samut Sakhon; Chachoengsao; Suphan Buri; Nakhon Sawan: Phayao; Petchabun; Phrae; Uttaradit; Satun; and Yala. 19 community hospitals, three provincial hospitals, and one regional hospital were included in the sample. The descriptive statistics of the variables used to estimate the unit cost estimation models, including the sample means, standard deviations, maximum and minimum values are provided in Tables 4-5 and 4-6.

Table 4-5: Descriptive statistics: cost proportion of patient services variables

Variables	Mean Value	Std. Dev.	Minimum	Maximum
(Dependent variable)				
CPS/FC	0.900	0.048	0.814	0.985
(Explanatory variables)				
BED	130	162	30	509
OCP	0.697	0.222	0.325	1.032
LOS	3.772	0.878	2.542	5.753
N = 18				

Table 4-6: Descriptive statistics: unit cost ratio estimation variables

Variables	Mean Value	Std. Dev.	Minimum	Maximum
(Dependent variable)				
OPUC/IPUC	0.070	0.028	0.028	0.118
(Explanatory variables)				
BED	130	162	30	509
OCP	0.724	0.305	0.325	1.649
LOS	3.803	0.829	2.542	5.753
N = 23				

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[1] Assavasamrit N (1999); Mahasaksiri L (2000); Tungkasamesamran K (2001); Sinsunksakul T (2001); Tisayaticom K & Thonimit D (2001); Tasilasathean M (2002); Cook N (2002); Jansaropas T (2003); Laekawipat S (2004); and Thawornboon C (2005).

4.2 Empirical results and analyses

This Section provides the empirical results of the estimation of the cost function and the unit cost estimation model. Whilst several regression models have been run and compared for goodness of fits, only those with the best fits are presented here. The results of the other tested regression models are provided as Appendices.

4.2.1 Empirical results for the cost function

Since the parameter estimation provided a theory inconsistent result for the long-run cost function[2], the short-run was preferred on theoretical grounds. Therefore the short-run cost function was emloyed for further analyses. After running the initial regression model (3-21 jointly with 3-22)[3], some adjustments were made before finalising the specification of the cost function. The results of the parameter estimations for the final specification are provided in Table 4-7[4]. The estimation was performed by Iterative SUR method where convergence was achieved after 14 weight matrices and 15 coefficient iterations.

2 See Appendix B for Eviews' estimation.
3 See Appendix C for EViews' estimation of the initial regression run.
4 See Appendix D for EViews' estimation.

Table 4-7: Estimation of the cost function parameters

Variable	Parameter	Estimate	t-statistic	p-value
Constant	α_0	2.334342	4.664	0.0000
*ln*IPD	β_1	0.292254	3.364	0.0008
*ln*OPD	β_2	0.168242	1.314	0.1888
*ln*LOS	β_3	0.064647	0.382	0.7022
(*ln*IPD)^2	β_{11}	0.037124	2.510	0.0121
(*ln*OPD)^2	β_{22}	0.162959	8.640	0.0000
(*ln*LOS)^2	β_{33}	−0.005972	−0.211	0.8327
*ln*IPD*ln*OPD	β_{12}	−0.053831	−3.846	0.0001
*ln*IPD*ln*LOS	β_{13}	0.026798	1.355	0.1754
*ln*OPD*ln*LOS	β_{23}	−0.052517	−2.457	0.0141
*ln*MD	γ_1	0.009279	0.694	0.4875
*ln*RN	γ_2	0.363176	8.316	0.0000
*ln*MED	γ_3	0.190195	8.072	0.0000
*ln*NMED	γ_4	0.083056	7.142	0.0000
*ln*MAT	γ_5	0.354294	7.264	0.0000
(*ln*MD)^2	γ_{11}	0.013480	6.072	0.0000
(*ln*RN)^2	γ_{22}	0.200380	17.567	0.0000
(*ln*MED)^2	γ_{33}	0.096123	12.208	0.0000
(*ln*NMED)^2	γ_{44}	0.012166	4.598	0.0000
(*ln*MAT)^2	γ_{55}	0.226111	131.160	0.0000
*ln*MD*ln*RN	γ_{12}	−0.009252	−2.456	0.0141
*ln*MD*ln*MED	γ_{13}	0.004445	1.528	0.1265
*ln*MD*ln*NMED	γ_{14}	0.005300	3.263	0.0011
*ln*MD*ln*MAT	γ_{15}	−0.013973	−12.491	0.0000
*ln*RN*ln*MED	γ_{23}	−0.044831	−5.427	0.0000
*ln*RN*ln*NMED	γ_{24}	−0.005123	−1.271	0.2040
*ln*RN*ln*MAT	γ_{25}	−0.141174	−52.055	0.0000
*ln*MED*ln*NMED	γ_{34}	0.001442	0.444	0.6569
*ln*MED*ln*MAT	γ_{35}	−0.057179	−30.323	0.0000
*ln*NMED*ln*MAT	γ_{45}	−0.013785	−13.570	0.0000
*ln*MD*ln*IPD	δ_{11}	0.004517	2.739	0.0062
*ln*MD*ln*OPD	δ_{12}	−0.010156	−5.591	0.0000
*ln*MD*ln*LOS	δ_{13}	0.011322	4.186	0.0000
*ln*RN*ln*IPD	δ_{21}	0.000532	0.099	0.9211
*ln*RN*ln*OPD	δ_{22}	−0.087203	−14.846	0.0000

Variable	Parameter	Estimate	t-statistic	p-value
*ln*RN*ln*LOS	δ_{23}	0.064530	7.322	0.0000
*ln*MED*ln*IPD	δ_{31}	0.006369	2.195	0.0282
*ln*MED*ln*OPD	δ_{32}	−0.034796	−10.880	0.0000
*ln*MED*ln*LOS	δ_{33}	0.014930	3.160	0.0016
*ln*NMED*ln*IPD	δ_{41}	−0.000997	−0.704	0.4815
*ln*NMED*ln*OPD	δ_{42}	−0.011796	−7.523	0.0000
*ln*NMED*ln*LOS	δ_{43}	0.009815	4.229	0.0000
*ln*MAT*ln*IPD	δ_{51}	−0.010421	−1.740	0.0820
*ln*MAT*ln*OPD	δ_{52}	0.143951	22.172	0.0000
*ln*MAT*ln*LOS	δ_{53}	−0.100597	−10.294	0.0000
*ln*BED	κ_{1}	0.371846	4.423	0.0000
$(ln\text{BED})^2$	κ_{11}	0.060898	4.897	0.0000
*ln*MD*ln*BED	τ_{11}	0.008518	5.795	0.0000
*ln*RN*ln*BED	τ_{21}	0.076292	15.699	0.0000
*ln*MED*ln*BED	τ_{31}	0.009173	3.542	0.0004
*ln*NMED*ln*BED	τ_{41}	0.006184	4.887	0.0000
*ln*MAT*ln*BED	τ_{51}	−0.100168	−18.411	0.0000
*ln*IPD*ln*BED	π_{11}	0.004871	0.481	0.6305
*ln*OPD*ln*BED	π_{21}	−0.076944	−6.885	0.0000
*ln*LOS*ln*BED	π_{31}	0.036290	1.979	0.0478
OPUC	η_{3}	0.000622	4.526	0.0000
LOC1	φ_{1}	−0.011565	−2.870	0.0041
LOC2	φ_{2}	−0.009915	−2.539	0.0112
LOC3	φ_{3}	−0.007213	−1.842	0.0655
LEV	φ_{4}	−0.035054	−3.798	0.0001

N = 704 $\bar{R}^2 = 0.977334$

Outputs (IPD, OPD, LOS)

All of the first-order output variables have positive signs, which satisfy the regularity conditions of duality theorem. Whilst the inpatient service is significant, the outpatient service and the length of stay resulted insignificant at 10% level. For outpatient services, there is a high correlation with inpatient services (0.917371) and so multicollinearity was the primary suspect. Even though outpatient services are essential outputs to hospitals and hence its omission merely due to multicollinearity may result in severer specification bias, its omission was anyway tested. First the second-order variables, and then the first order variable were omitted. The model fit (adjusted R^2) declined steadily from 0.977334 to 0.965234, then to 0.957722[5]. Therefore the place for the outpatient services in the cost function seems to be secured. Anyway the hospital cost is more sensitive to inpatient volume, and the small and insignificant parameter for outpatient services implies a relatively unresponsive hospital cost to outpatient volume.

On the other hand, the correlation between length of stay and other variables are relatively modest, and the direct linkage to hospital cost may not be prominent. However, the estimated parameters for the interactions between length of stay and input prices are all significant at 1% level. In order to test for the robustness of the model specification by omitting the average length of stay in the same manner as above, the model fit declined from 0.977334 to 0.976020, then to 0.975994[6]. Therefore it seems reasonable to assume that the length of stay belongs to the cost function.

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[5] See Appendix E.
[6] See Appendix F.

The interaction terms between inpatient and outpatient as well as outpatient and length of stay are negatively correlated to hospital cost. These signs may indicate the existence of economies of scope which reduces the cost by jointly providing inpatient and outpatient services. This issue will be tested in Sub-section 4.4.2.

Inputs (MD, RN, MED, NMED, MAT, and BED)

All first-order input variables have positive signs, which is consistent with the pre-conditions for duality theorem. These parameters are the intercepts for the cost share equations and reflect the average cost share of the input factors when evaluated at the sample means of explanatory variables (Vita 1990; Alba 1995). Not surprisingly the nurse has the highest cost share of 36.3%. Nurse, other medial personnel, non-medical personnel, and material are highly significant at 1% level. Only the medical doctor is statistically insignificant.

The number of bed represents a proxy for the capital stock. The first-order parameter for bed is positive and highly significant. The significant and positive square terms implies that the cost elasticity with respect to capital increases with higher capital levels. A similar result was obtained by Cowing & Holtman (1983) and they interpreted this as an indication for over-capitalisation. This interpretation intuitively applies, on the isoquant of Figure 3-3, to a production point where the capital level is set above the long-run equilibrium. However, as Wagstaff & Barnum (1992) pointed out, the total cost can be decreased by reducing the capital at such a point without changing the output level, but the variable cost cannot: it always increases along the isoquant curve. Wagstaff & Barnum (*ibid.*) argued that this result, which is inconsistent with economic theory, implies that the variable cost used in the study may contain some fixed costs.

Other factors (CM, IPUC, OPUC)

Case-mix index, measured by average DRG-RW, is positively correlated with hospital cost. However, the estimated parameter is small and insignificant. The variable is correlated with outputs, number of beds and the level of hospital, and hence may be considered a redundant variable. Its omission resulted in a slightly better model-fit (adjusted R^2) from 0.977250 to 0.977267 without affecting the remaining parameters significantly[7], and so has been safely omitted from the cost function.

The proportion of UC patients in terms of inpatient and outpatient had the opposite signs. Higher proportion of UC in outpatient visits was significant and positively correlated with hospital costs. On the other hand, the proportion of UC in inpatient admissions had a negative sign and was statistically insignificant. This variable is highly correlated with the proportion of UC outpatients, and hence may be considered a redundant variable. Since its omission resulted in a better model-fit (adjusted R^2) from 0.977250 to 0.977319 without affecting the parameter estimations of the remaining variables, this variable has been safely removed from the cost function.

Dummies (LOC1, LOC2, LOC3, LEV)

All dummies for the regional locations of hospitals have negative signs and are significant. It seems that the central region has higher cost levels compared to other regions. The dummy for distinguishing the level of hospitals between community and provincial was significant and negatively correlated with the hospital cost.

Specification of the cost function

Based on the estimations above, the cost function takes the following specification:

---

[7] See Appendix C.

$$
\begin{aligned}
ln\mathrm{VC} = {} & 2.334342 + 0.292254 ln\mathrm{IPD} + 0.168242 ln\mathrm{OPD} + 0.064647 ln\mathrm{LOS} \\
& + (1/2)0.037124(ln\mathrm{IPD})^2 + (1/2)0.162959(ln\mathrm{OPD})^2 - (1/2)0.005972(ln\mathrm{LOS})^2 \\
& - 0.053831 ln\mathrm{IPD} ln\mathrm{OPD} + 0.026798 ln\mathrm{IPD} ln\mathrm{LOS} - 0.052517 ln\mathrm{OPD} ln\mathrm{LOS} \\
& + 0.009279 ln\mathrm{MD} + 0.363176 ln\mathrm{RN} + 0.190195 ln\mathrm{MED} \\
& + 0.083056 ln\mathrm{NMED} + 0.354294 ln\mathrm{MAT} \\
& + (1/2)0.013480(ln\mathrm{MD})^2 + (1/2)0.200380(ln\mathrm{RN})^2 + (1/2)0.096123(ln\mathrm{MED})^2 \\
& + (1/2)0.012166(ln\mathrm{NMED})^2 + (1/2)0.226111(ln\mathrm{MAT})^2 \\
& - 0.009252 ln\mathrm{MD} ln\mathrm{RN} + 0.004445 ln\mathrm{MD} ln\mathrm{MED} + 0.005300 ln\mathrm{MD} ln\mathrm{NMED} \\
& - 0.013973 ln\mathrm{MD} ln\mathrm{MAT} - 0.044831 ln\mathrm{RN} ln\mathrm{MED} - 0.005123 ln\mathrm{RN} ln\mathrm{NMED} \\
& - 0.141174 ln\mathrm{RN} ln\mathrm{MAT} + 0.001442 ln\mathrm{MED} ln\mathrm{NMED} \\
& - 0.057179 ln\mathrm{MED} ln\mathrm{MAT} - 0.013785 ln\mathrm{NMED} ln\mathrm{MAT} \\
& + 0.004517 ln\mathrm{MD} ln\mathrm{IPD} - 0.010156 ln\mathrm{MD} ln\mathrm{OPD} + 0.011322 ln\mathrm{MD} ln\mathrm{LOS} \\
& + 0.000532 ln\mathrm{RN} ln\mathrm{IPD} - 0.087203 ln\mathrm{RN} ln\mathrm{OPD} + 0.064530 ln\mathrm{RN} ln\mathrm{LOS} \\
& + 0.006369 ln\mathrm{MED} ln\mathrm{IPD} - 0.034796 ln\mathrm{MED} ln\mathrm{OPD} + 0.014930 ln\mathrm{MED} ln\mathrm{LOS} \\
& - 0.000997 ln\mathrm{NMED} ln\mathrm{IPD} - 0.011796 ln\mathrm{NMED} ln\mathrm{OPD} \\
& + 0.009815 ln\mathrm{NMED} ln\mathrm{LOS} - 0.010421 ln\mathrm{MAT} ln\mathrm{IPD} \\
& + 0.143951 ln\mathrm{MAT} ln\mathrm{OPD} - 0.100597 ln\mathrm{MAT} ln\mathrm{LOS} \\
& + 0.371846 ln\mathrm{BED} + (1/2)0.060898(ln\mathrm{BED})^2 \\
& + 0.008518 ln\mathrm{MD} ln\mathrm{BED} + 0.076292 ln\mathrm{RN} ln\mathrm{BED} + 0.009173 ln\mathrm{MED} ln\mathrm{BED} \\
& + 0.006184 ln\mathrm{NMED} ln\mathrm{BED} - 0.100168 ln\mathrm{MAT} ln\mathrm{BED} \\
& + 0.004871 ln\mathrm{IPD} ln\mathrm{BED} - 0.076944 ln\mathrm{OPD} ln\mathrm{BED} + 0.036290 ln\mathrm{LOS} ln\mathrm{BED} \\
& + 0.000622\mathrm{OPUC} - 0.011565\mathrm{LOC}_1 - 0.009915\mathrm{LOC}_2 - 0.007213\mathrm{LOC}_3 \\
& - 0.035054\mathrm{LEV} + \varepsilon \qquad (4\text{-}1)
\end{aligned}
$$

4.2.2 Empirical results for unit cost estimation

There were two regressions run for the estimation of unit costs of inpatient and outpatient from the total hospital cost. The first regression was to estimate the cost proportion of patient services over the total cost. The proportion is used to exclude the costs incurred for services other than inpatient and outpatient services, such as health promotion activities, which corresponds to the Steps 1 to 4 of Figure 3-4. The second regression was run to model the unit cost ratio between inpatient and outpatient services so that each unit cost can be estimated from the patient service cost. The parameters of the model were estimated by OLS method.

Cost proportion of patient services

The Breusch-Pagan-Godfrey test revealed no evidence for heteroskedasticity[8], and so OLS may be an acceptable estimation method for this study. In the initial regression run with Expression 3-23, all dummies and the average length of stay were insignificant[9]. Several specifications were tested by comparing different omission patterns of insignificant variables[10]. The option with the best fit in terms of Akaike Information Criterion (AIC) or Schwarz Criterion (SC)[11] was selected as the model for estimating the cost proportion of patient services as shown in Table 4-8.

Table 4-8: Parameter estimations for cost proportion of patient services

Variable	Parameter	Estimate	t-statistic	p-value
Constant	θ_0	−0.249169	−5.879	0.0000
*ln*BED	θ_1	0.056328	5.490	0.0001
*ln*OCP	θ_2	0.043438	1.940	0.0728
*ln*LOS	θ_3	−0.062779	−1.343	0.2005
N = 18	$\bar{R}^2 = 0.742318$			

The result seems to provide an acceptable model-fit to explain the proportion of the

8 See Appendix G for the test result on heteroskedasticity.
9 See Appendix H for EViews' estimation of the initial regression run.
10 See Appendix I for EViews' estimations for various specifications.
11 The one with lowest AIC or SC is the best model-fit.

patient service cost over the total hospital cost. However, the accuracy may not be at the level to be convinced to use for decision-makings. This may primarily due to the insufficient sample size which was available for this study.

The final model takes the following specification:

$$\ln(\text{CPS/TC}) = -0.249169 + 0.056328\ln\text{BED} + 0.043438\ln\text{OCP} - 0.062779\ln\text{LOS} + \upsilon_p. \quad (4\text{-}2)$$

Unit cost ratio between outpatient and inpatient services

The Breusch-Pagan-Godfrey test did not detect any evidence for heteroskedasticity[12]. However, the initial regression run with the expression 3-24 provided disappointing results where none of the explanatory variables were significant at 5% level[13]. Correlations between different explanatory variables were investigated, but no significant correlations were identified.

One of the causes of this result could be attributed to the small sample size. However, it is difficult to increase the sample since the dependent variable is not routinely available. Another issue may be attributed to specification errors. Since there is yet an established theory behind the specification for the unit cost ratio estimation, it may require some time to model this regression with sufficient accuracy.

Several omissions of explanatory variables have been tested[14] and the one with the lowest AIC or SC was selected as the specification for this regression model. The parameter estimations for the model with the best fit is provided as per Table 4-9[15].

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12 See Appendix G for the test result on heteroskedasticity.

13 See Appendix J for EViews' estimation of the initial regression run.

14 See Appendix K for EViews' estimations for various specifications.

15 Even though the variables included in the model were not all significant, the consistency of signs with expectations was considered sufficient to justify their inclusion.

Table 4-9: Parameter estimations for unit cost ratio

Variable	Parameter	Estimate	t-statistic	p-value
Constant	ς_0	−2.494032	−25.107	0.0000
*ln*OCP	ς_1	0.210862	1.286	0.2140
LEV1	ρ_1	−0.818367	−4.693	0.0002
LEV2	ρ_2	−0.700755	−2.148	0.0448
N = 23	$\bar{R}^2 = 0.521177$			

The final model for unit cost ratio estimation takes the following specification:

$$ln(UCOP/UCIP) = -2.494032 + 0.210862\,lnOCP - 0.818367LEV_1 - 0.700755LEV_2 + \upsilon_u. \quad (4\text{-}3)$$

4.3 Cost simulations

Based on the estimated cost function and the unit cost estimation models, the actual values and the estimated (fitted) values were compared. The unit costs of average hospitals were also estimated for different levels.

4.3.1 Total cost simulation

Recalling from Sub-section 3.4.1, the total cost of a hospital in the short-run is expressed as:

$$C = VC + FC = f(w_1,w_2,K) + rK. \quad (3\text{-}5)$$

Therefore the total cost was derived by adding up the estimated VC from the cost function and the actual capital cost which was obtained from MOPH for year 2006. The estimation of total cost took the following steps:

1) Plugging the actual values of the explanatory variables into the Expression 4-1 for each sampled hospital;
2) Calculating the dependent variables *ln*(VC);

3) Anti logging the dependent variables by means of VC = $e^{ln(VC)}$;

4) Adding the actual capital values to VCs to obtain the total costs of individual hospitals; and

5) Averaging the estimated total costs for different categories.

Table 4-10 presents the comparisons of the actual total costs and the estimated total costs of average hospitals at each level and region[16].

Table 4-10: Comparisons of actual vs. estimated total costs of average hospitals

Hospital level	Region	(sample size)	Actual (THB)	Estimated (THB)	% error
Community	**Total**	**(614)**	**69,022,947**	**69,452,107**	**0.62**
	Central	(150)	71,247,473	71,041,321	−0.29
	East	(221)	68,814,660	71,263,197	3.56
	North	(133)	71,881,553	72,446,919	0.79
	South	(110)	62,951,657	60,025,355	−4.65
Provincial	**Total**	**(90)**	**747,533,513**	**670,962,608**	**−10.24**
	Central	(35)	710,645,836	645,635,191	−9.15
	East	(17)	895,452,017	782,426,310	−12.62
	North	(20)	744,905,898	675,067,405	−9.38
	South	(18)	682,478,314	610,378,202	−10.56

The average community hospitals seem to have reasonable estimations. Even though there is a slight over-estimation, it is possibly due to the larger estimations of parameters accounting for the provincial hospitals, which probably have higher cost elasticities than community hospitals. On the other hand, the provincial hospitals have relatively large under-estimations. Even though the underlying cause of such an irregularity is not self-evident, some analyses are in order.

The potentially different cost elasticities in terms of size between community and provincial hospitals were not accounted for in the estimation. Whilst a dummy variable was included to account for the difference of cost levels between the two

16 Comparisons of individual hospitals are graphically illustrated in Appendix L.

levels of hospitals, it was not interacted with other variables and hence assumed homogenous cost elasticities in terms of size for both community and provincial hospitals. Table 4-11 provides the different levels of average cost increases between smaller and larger hospitals.

Table 4-11: Cost differences between smaller and larger hospitals

	Average total cost of hospitals below the mean value (THB)	Average total cost of hospitals above the mean value (THB)	Difference in proportion
(Community: mean value = 69,022,947)			
Actual value	45,166,539	107,764,122	2.39
Estimated value	44,378,939	110,169,218	2.48
(Provincial: mean value = 747,533,513)			
Actual value	463,401,025	1,262,523,648	2.72
Estimated value	420,615,947	1,124,715,931	2.67

For community hospitals, the estimated total cost increases at a higher speed compared to the actual one (2.48 > 2.39). This roughly implies, though not precisely, a higher cost elasticity of the estimated cost function relative to the actual one. However, the provincial hospitals have the opposite relationship where the increase of estimated total cost is slower than the actual one (2.67 < 2.72). If the increases in actual total costs are compared between community and provincial hospitals, the latter one increases at a higher rate (2.39 < 2.72), which implies different cost elasticities between these two groups. The addition of interaction terms between the provincial dummy and other variables might have enabled to account for the differences in the "shape" of the cost function. However, such interaction terms were not added after considering the balance between its potential benefit and its draw-back of significant increase in the number of parameters which could become unmanageable.

The SUR method with iterations until convergence would provide a maximum likelihood estimates (Christensen & Greene 1976) where the parameters would be estimated in a way to maximise the chance to predict the observed values. In this connection, the SUR would have placed its estimations of parameters so that the shape of the cost function would better reflect the cost behaviour of community hospitals which comprise the majority of samples.

Another issue, though not quite convincing, may be attributed to some outliers among the sampled hospitals which might have shifted the overall cost function down-wards particularly for provincial hospitals. Omissions of some potential outliers were tested whether they would improve the balance of errors. The tests provided slightly better estimations for provincial hospitals. However, it was not evident weather such outlier samples provided inaccurate cost information which could justify their omissions. Therefore the potential bias which would be caused by excluding some hospitals favoured the retention of the original samples.

4.3.2 Unit cost simulation

The unit cost of hospitals were estimated and compared with the actual findings from past studies. 18 samples which had full data of the variables were compared in terms of actual and estimated unit costs. The estimation of unit costs took the following steps:

1) Plugging the actual values of explanatory variables into the Expression 4-2;
2) Calculating the dependent variable *ln*(CPS/FC);
3) Anti logging the dependent variable by means of CPS/FC = $e^{ln(CPS/FC)}$;
4) Deriving the amount of CPS by CPS/FC x FC;
5) Plugging the actual values of explanatory variables into the Expression 4-3;
6) Calculating the dependent variable *ln*(UCOP/UCIP);
7) Anti logging the dependent variable by means of UCOP/UCIP = $e^{ln(UCOP/UCIP)}$;

8) Calculating the inpatient unit cost by means of UCIP = CPS / [# outpatient visits x (UCOP/UCIP) + # inpatient admissions]; and

9) Calculating the outpatient unit cost by means of UCIP = UCIP x (UCOP/UCIP).

Table 4-12 provides the comparison of the actual and estimated unit costs of the sampled hospitals with full information on patient service cost.

Table 4-12: Comparison of actual vs. estimated unit cost

Province	Hospital level	UCOP (THB)			UCIP (THB)		
		Actual	Est.	% Error	Actual	Est.	% error
Buri Ram	Community	280.79	235.16	−16.25	3,813.65	3,545.98	−7.02
Buri Ram	Community	137.87	134.46	−2.47	3,276.00	2,026.69	−38.14
Chanchoangsao	Community	285.93	283.00	−1.02	3,810.49	3,926.98	3.06
Nakornsawan	Community	102.82	140.01	36.17	2,517.11	1,822.45	−27.60
Nakornsawan	Community	232.70	202.54	−12.96	2,112.80	2,479.26	17.34
Nakornsawan	Community	310.41	260.37	−16.12	2,630.56	3,427.35	30.29
Nakornsawan	Community	179.32	169.37	−5.55	1,940.57	2,050.78	5.68
Nonthaburi	Provincial	251.00	267.61	6.62	8,112.00	7,722.24	−4.80
Patumtani	Community	307.08	257.73	−16.07	3,216.56	3,956.51	23.00
Patumtani	Community	230.50	232.81	1.00	3,069.39	3,307.03	7.74
Payao	Provincial	376.73	306.34	−18.68	8,147.42	8,746.43	7.35
Payao	Community	133.05	190.37	43.08	2,958.06	2,290.18	−22.58
Payao	Community	239.76	226.74	−5.43	2,546.73	2,762.83	8.49
Petchaboon	Community	349.08	279.73	−19.87	3,369.75	3,406.07	1.08
Phrae	Community	243.46	223.92	-8.03	2,909.85	2,440.08	−16.14
Samut Prakan	Community	257.94	245.64	−4.77	3,212.24	3,363.39	4.71
Samutsakorn	Provincial	181.43	195.64	7.83	6,480.93	6,414.42	−1.03
Samutsakorn	Community	124.36	149.91	20.55	2,429.25	2,046.44	−15.76
Satun	Community	304.10	291.56	−4.12	4,230.92	4,169.25	−1.46
Suphanburi	Regional	388.62	389.36	0.19	9,778.40	9,797.02	0.19
Uttaradit	Community	298.16	304.33	2.07	4,214.74	3,858.08	−8.46
Yala	Provincial	162.56	167.67	3.14	5,510.79	5,253.45	−4.67
Yala	Community	112.17	94.24	−15.98	1,017.93	1,184.28	16.34

The estimations seem to be reasonable in roughly approximating the levels of unit costs. However, it should also be noted that there are some fairly large errors in terms of percentage which may pose a question on the applicability on various decision making situations.

Table 4-13 provides the estimated unit costs for average hospitals used in the cost function model.

Table 4-13: Unit cost simulations for average hospitals

		Estimated (THB)		Unit cost ratio
Hospital level	Region	UCOP	UCIP	(UCOP:UCIP)
Community	Central	455.12	5,785.70	1 : 12.71
	East	425.18	5,283.76	1 : 12.43
	North	473.20	5,964.50	1 : 12.60
	South	435.88	5,494.83	1 : 12.61
Provincial	Central	617.43	17,463.47	1 : 28.28
	East	508.66	14,121.29	1 : 27.76
	North	581.13	16,226.86	1 : 27.92
	South	570.21	15,975.59	1 : 28.02

Generally the estimated unit costs seem to be at higher levels compared to those included in Table 4-12. It may be caused by the fact that more than half of the samples in the estimations for Table 4-12 did not include the capital and hence look lower. Other underlying causes may include inflation and general health expenditure escalation. Nonetheless the unit cost ratio between outpatient and inpatient for community hospitals is roughly 1:13 which is close to the current MOPH practice of using 1:14 as the rule-of-thumb.

However, the unit costs of provincial hospitals, particularly inpatient unit costs, seem to be much higher than one would expect. The unit cost ratio between outpatient and inpatient is roughly 1:28, which is significantly different from the current MOPH practice of using 1:18 for provincial hospitals. At the face value, this finding suggests that the current MOPH practice underestimates and overestimates the unit costs of inpatient and outpatient respectively. This may have an implication on resource allocation which should be adjusted between these two services. However, this issue will be discussed in Sub-section 4.5.2.

4.4 Economies of scale & scope

Using the estimated parameters of the short-run variable cost function, economies of scale and scope were investigated. The methods are drawn from the options discussed in Section 3.7.

4.4.1 Economies of scale

Whilst the long-run cost function provided theory inconsistent results and hence was rejected in this study, there were two methods available for estimating the scale economies for the short-run variable cost function: using the optimal quantity of capital K*; and using the actual quantity of K. Since the short-run was selected due to the theory inconsistent result obtained for the long-run total cost function, it is reasonable to assume that the quantity of capital is relatively slow in its adjustment to the cost-minimising level. Under this assumption, it is reasonable to use the actual quantity of K in estimating the ray scale economies:

$$\text{EScale} = \frac{1 - \partial ln\text{VC}/\partial ln\text{K}}{\sum(\partial ln\text{VC}/\partial ln\text{Q}_i)} \quad . \tag{3-28}$$

EScale > 1 implies the existence of economies of scale, and EScale <1 diseconomies of scale. The estimation process is described as follows:

1) Deriving each derivative (cost elasticities with respect to capital and outputs):

$\partial ln\text{VC}/\partial ln\text{K} =$ 0.371846 + 0.060898*ln*BED + 0.008518*ln*MD + 0.076292*ln*RN + 0.009173*ln*MED + 0.006184*ln*NMED − 0.100168*ln*MAT + 0.004871*ln*IPD − 0. 0.076944*ln*OPD + 0.036290*ln*LOS

$\partial ln\text{VC}/\partial ln\text{Q}_1 =$ 0.292254 + 0.037124*ln*IPD − 0.053831*ln*OPD + 0.026798*ln*LOS + 0.004517*ln*MD + 0.000532*ln*RN + 0.006369*ln*MED − 0.000997*ln*NMED − 0.010421*ln*MAT + 0.004871*ln*BED

$\partial ln\text{VC}/\partial ln\text{Q}_2 =$ 0.168242 + 0.162959*ln*OPD − 0.053831*ln*IPD − 0.052517*ln*LOS − 0.010156*ln*MD − 0.087203*ln*RN − 0.034796*ln*MED − 0.011796*ln*NMED + 0.143951*ln*MAT − 0.076944*ln*BED

$\partial ln\text{VC}/\partial ln\text{Q}_3 =$ 0.064647 − 0.005972*ln*LOS + 0.026798*ln*IPD − 0.052517*ln*OPD + 0.011322*ln*MD + 0.064530*ln*RN + 0.014930*ln*MED + 0.009815*ln*NMED − 0.100597*ln*MAT + 0.036290*ln*BED ; and

2) Plugging the average variables from Table 4-4 into the above derivatives to estimate the EScale for each level and region of hospitals by Expression 3-28.

The results of ray economies of scale are provided in Table 4-14[17].

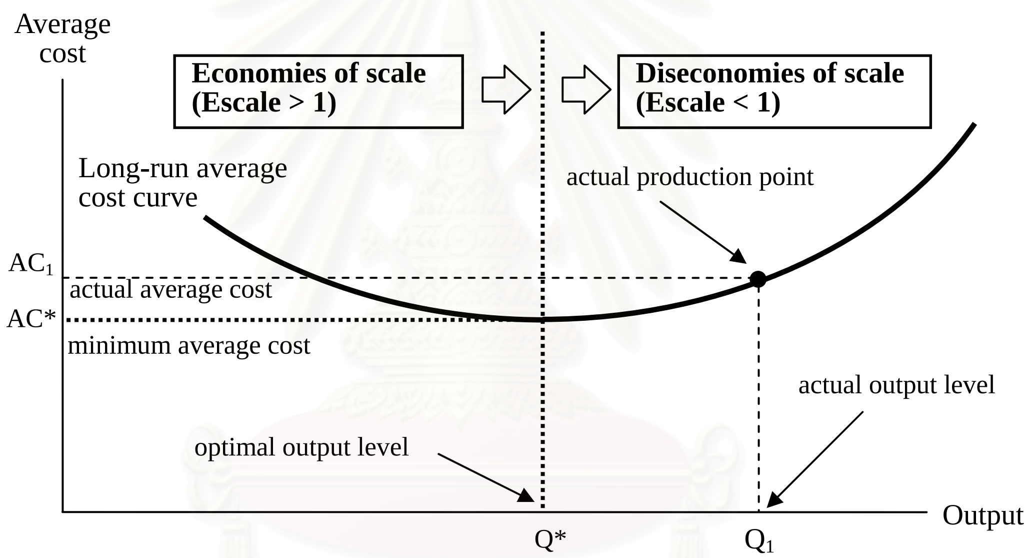
Table 4-14: Ray economies of scale by hospital levels and regions

Hospital level	Region	$\frac{\partial ln VC}{\partial ln K}$	$\frac{\partial ln VC}{\partial ln Q_1}$	$\frac{\partial ln VC}{\partial ln Q_2}$	$\frac{\partial ln VC}{\partial ln Q_3}$	$\sum\left(\frac{\partial ln VC}{\partial ln Q_i}\right)$	EScale
Community	Central	**0.20495**	0.07828	0.65733	0.21609	**0.95171**	**0.83539**
	East	**0.21090**	0.08408	0.64008	0.22903	**0.95319**	**0.82785**
	North	**0.20392**	0.08105	0.65537	0.21336	**0.94978**	**0.83817**
	South	**0.20970**	0.08358	0.63949	0.22513	**0.94820**	**0.83348**
Provincial	Central	**0.16955**	0.09085	0.71431	0.17559	**0.98075**	**0.84674**
	East	**0.16061**	0.10143	0.70761	0.18211	**0.99115**	**0.84689**
	North	**0.16424**	0.09586	0.71431	0.17469	**0.98486**	**0.84861**
	South	**0.16543**	0.09335	0.71184	0.17867	**0.98386**	**0.84826**

17 The economies of scales for individual hospitals are graphically illustrated in Appendix M.

In all regions and levels of hospitals, the EScale is smaller than 1 or diseconomies of scale exists. For instance, a 10% increase in the levels of all outputs of an average community hospital in the Central region will yield an 11.97% (10/0.835391) increase of total variable cost. It implies, at face value, that the hospitals are relatively large and their efficiencies may be improved by breaking down to smaller-sized facilities. Figure 3-6 illustrates the production point of the sampled hospitals on the long-run average cost curve.

Figure 4-1: Actual level of output on the long-run average cost curve



4.4.2 Economies of scope

Since the detailed breakdown data of outputs for each department of hospitals were not available, only inpatient and outpatient services entered the cost function as outputs. Data for other services such as laboratory or x-ray were also not available. Therefore, only the relations between outpatient and inpatient (and average length of stay) were tested for the scope economies. Even though community and public hospitals may not be separated to outpatient and inpatient facilities, their balance of service volumes (such as having more outpatients) may pose a question whether a stand-alone outpatient clinic may be added or the capacity of the existing outpatient department in the hospital be expanded.

Among the two methods described in Sub-section 3.7.2, the primary one (Expression 3-29) was unable to use due to imprecise estimates of costs obtained by setting the outputs to near zero (small numbers such as 0.1 or 1 were tested since *ln*0 is not defined). Many studies which employed the translog function have encountered similar problems (Vita 1990; Alba 1995). Therefore the second method (Expression 3-31) by referring to WCC was employed in this study. Table 4-15 provides the result in testing for WCC.

Table 4-15: Test for weak cost complementarities

Formula[18]	Estimate	t-statistic	χ^2-statistic[19]	p-value	Significance at 5% level
$\beta_1\beta_2 + \beta_{12}$	−0.004662	–	0.0168	0.8970	Insignificant
$\beta_2\beta_3 + \beta_{23}$	−0.041640	–	5.5336	0.0187	Significant
π_1	0.004871	0.481	–	0.6305	Insignificant
π_2	−0.076944	−6.885	–	0.0000	Significant
π_3	0.036290	1.979	–	0.0478	Significant

The evaluation for economies of scope is not straightforward since the values for $\partial K^*/\partial Q_j$ are not known in Expression 3-31. However, under the assumptions that $\partial K^*/\partial Q_j > 0$ and interpreting the insignificant estimates from Table 4-15 as 0, WCC for the estimated short-run cost function would be:

1) $\beta_1\beta_2 + \beta_{12} + \pi_2(\partial K^*/\partial Q_2) = 0 - 0.076944\ (\partial K^*/\partial Q_2)$ = Negative;

2) $\beta_2\beta_1 + \beta_{21} + \pi_1(\partial K^*/\partial Q_1) = 0 + 0(\partial K^*/\partial Q_1) = 0$;

3) $\beta_2\beta_3 + \beta_{23} + \pi_3(\partial K^*/\partial Q_3) = -\ 0.041640 + 0.036290\ (\partial K^*/\partial Q_1)$ = inconclusive; and

4) $\beta_3\beta_2 + \beta_{32} + \pi_2(\partial K^*/\partial Q_2) = -\ 0.041640 - 0.076944\ (\partial K^*/\partial Q_2)$ = Negative. (4-4)

18 $\beta_1\beta_3 + \beta_{13}$ was not tested since IPD and LOS are inseparable.

19 H_0: $\beta_1\beta_2 + \beta_{12} = 0$ and $\beta_2\beta_3 + \beta_{23} = 0$ were tested by Walt test. See Appendix N for EViews' test results.

These results can be interpreted as follows:

1) The marginal cost of Q_2 (outpatient visits) will decrease with the increase of Q_1 (inpatient admissions);
2) The marginal cost of Q_1 (inpatient admissions) will not be affected by the increase of Q_2 (outpatient visits);
3) The marginal cost of Q_3 (average length of stay) may or may not decrease with the increase of Q_2 (outpatient visits); and
4) The marginal cost of Q_2 (outpatient visits) will decrease with the increase of Q_3 (average length of stay).

From 1) and 2), it may be reasonable to assume that economies of scope partially exists for the "average" hospital in that the marginal cost of outpatient services will fall with an increase in inpatient admissions (however, not the other direction). From 3) and 4), it may also be reasonable to assume that partial economies of scope exists for the "average" hospital in that the marginal cost of outpatient services will fall with an increase in average length of stay of inpatients (however, the other direction is inconclusive). They imply, in the above examples, that expanding the existing outpatient department of a hospital (which at least may not result in an increase of inpatient unit cost) is preferred over having an additional stand-alone clinic (which may result in an increase of outpatient unit cost).

4.5 Discussion

4.5.1 Cost function

The TMCF demonstrated a good fit in describing the cost structure of public hospitals at least near the approximation point. The adjusted R^2 of 0.977334 is sufficiently high for a cross-sectional study. Therefore several analyses which followed the estimation of cost function, such as economies of scale or scope, may provide reasonable implications.

All the first-order output and input parameters provided positive signs, which are consistent with the requirement of theories. In terms of output variables, it was not clear at the initial stage whether the inclusion of LOS (average length of stay) may make sense at all. Most of the studies from the literature, except for those from Vita (1990) and Grannemann *et al*. (1986), employed only one out of three types of variables to describe the inpatient output: admission; discharge; or bed-day. Some review articles favour the discharge measure over bed-day since it is considered the “true” output while bed-day is considered a “process” output. Given the result from Table 4-7, both *ln*LOS and $(ln\text{LOS})^2$ are highly insignificant which pose a question on the justification of its inclusion in the cost function. However, the interaction terms between LOS and factor inputs are all highly significant even at 1% level, and the signs are consistently positive with labour inputs whilst it is negative with material. These findings may imply a changing resource mix with prolonged stay of patients. It seems reasonable when considering the increasing labour costs for care with prolonged stay of inpatients (positive signs for labour inputs) yet decreasing intensity of treatment and resource use such as drugs and supplies (negative sign for the material). Perhaps the changing nature of resource mix may not be fully captured by one variable only, and so the place for LOS seems to be warranted in the function.

Amongst the input factors, MD is highly insignificant even at 10% level. Given that the other input factors are all significant at 1% level, the inconsistency of MD variable may deserve due attention. One of the reasons behind this issue may be the high standard deviation of wage levels of doctors (THB 5,490 from Table 4-2). Although experienced medical doctors receive significantly high wages than other hospital staff members, the low average wage indicates a relatively younger age distribution among the sample hospitals. It may partially be due to the Thai system for health manpower distribution in which the newly graduated medical doctors are posted at least three years in rural areas where the majority of community hospitals are located. Another potential reason may be that the medical doctors are in fact fixed inputs. Cowing & Holtman (1983) treated the physicians as fixed input to the hospital together with the number of beds. However, the position of medical doctors employed at public hospitals in Thailand is very different from the physicians working at hospitals in the USA, and hence cannot be compared in the same manner. However, the quantity of medical doctors might be even slower to adjust to the output levels compared to other labour inputs or materials. This assumption, however, requires further investigations which are well beyond the scope of this study.

The interpretation of the positive sign for BED is rather controversial. Aletras (1999) interpreted this result in a similar way as Cowing & Holtman (1983) which indicated the existence of over-capitalisation. Dor & Farley (1996) analysed the variable cost function in a fixed effect model for a three years' panel data set, and accounted the positive sign of capital for the different accounting practices on capital depreciation where new capitals employ different rates than old. However, this argument would not apply if the number of beds is used as the proxy for capital stock. Alba (1996) suggested another interpretation in addition to the argument of Wagstaff & Barnum (1992) (see Sub-section 4.2.1) for the positive relationship between the capital and variable cost. He raised the issue of the changing nature of hospital's technology with the addition of new capitals, which in turn shifts the isoquant curve and may result in an increase of variable cost. Several interpretations may be possible for the application to this study even though two issues may prevail. First, the argument of Wagstaff & Barnum (*ibid.*) may be reasonable that some fixed costs are included in the variable cost, since labour inputs are relatively slow to adjust particularly if it is determined centrally, rather than in the market mechanism, which is the case for public hospitals in Thailand. Another issue may be that the capitals are not adjusted to the long-run cost-minimising levels. Whilst the quantity of capital is not defined by the market condition, it may be tedious to assume a long-run equilibrium. This issue may be further supported by the fact that the long-run cost function was rejected due to theory inconsistent results[20].

The case-mix index, which is represented by the average DRG-RW, was omitted even though the case-mix has been widely recognised as one of the primary variable to be included in addition to output and input variables. However, its omission does not mean that the case-mix has no role in determining the hospital costs. It may be reasonable to assume that hospitals with larger capacities are generally associated with severer cases, and so its effect might have already been captured by other variables reflecting the "size" of hospitals (output levels, number of beds, level of hospitals etc.).

It seems that UC is indeed one of the causes of cost escalation of public hospitals in Thailand. The significant and positive sign for UCOP may imply that the expected cost containment from capitation-based financing is insufficient in controlling the escalating demand for healthcare. The negative sign of UCIP, on the other hand, may indicate some cost containment behaviour through DRG-based payment mechanism. However, its statistical insignificance may merely imply a high correlation with UCOP and hence may be interpreted as being redundant.

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[20] See Appendix B.

The negative sign of the dummy variable LEV for provincial hospitals is statistically significant. At the face value, it may be interpreted that the unit cost for patient services is lower for provincial hospitals compared to community hospitals. If this is the case, the result is consistent with the findings from Supachutikul (1996) where the smaller hospitals (less than 200 beds) have higher inpatient unit costs compared to medium-sized hospitals (200−600 beds). However, from the cost simulation result in Table 4-13, it does not seem to be the case. Even though the negative sign for LEV may imply a lower unit cost *ceteris paribus* (setting other variables constant), it may not be sufficiently large compared to the effects from other factors which shifts the level of unit costs upwards (such as case-mix or length of stay).

The different accuracies of cost simulations between community and provincial hospitals suggest that the cost function not be used to forecast the cost of provincial hospitals. Some analyses on this matter were attempted in Sub-section 4.3.1. However, even for the community hospitals, the individual cost simulations suggest that the error tend to be relatively higher for those hospitals which are distant from the average size. It is consistent with the property of a translog cost function which was discussed by Vita (1990) in Sub-section 2.2.2. Therefore the cost function may be reasonably used to predict the cost of community hospitals in a simulation with a relatively narrow range of changes in variables, but not for simulations which involve major changes in size (such as merger or upgrading of hospitals).

4.5.2 Unit cost estimation

The developed models for estimating the unit costs of hospitals are not able to be considered very satisfactory. The major limitation of this study was the apparently insufficient sample data in terms of size and comparability. A sample size of 23 is not sufficient in itself. In addition, the small size was further broken down to different categories in terms of levels of hospitals, years of studies, surrounding health system and environment (before/after UC, before/after financial crisis etc.), which further questions the degree of representation of samples from the target population.

The accuracy of unit cost simulations is somewhat mixed. The estimation for community hospitals provides a fairly reasonable result. In this connection, the current "rule of thumb" adopted by MOPH to assume 1:14 unit cost ratio for outpatient visit and inpatient admission for community hospitals seems to be reasonable, even though the occupancy rate can vary the level of inpatient unit cost and hence the ratio. On the other hand, the simulations for provincial hospitals provided significantly different results compared to the current MOPH practice. It may suggest that the unit cost ratio used by MOPH would have to be changed in order to estimate the unit costs more accurately. However, the small sample size employed for this study (only three provincial hospitals out of 23 samples in total) is apparently not sufficient to be convinced that the difference must be taken into account. An increased number of observations would significantly improve the accuracy of the estimations. Therefore it may not be possible at this stage to provide a reasonable indication on the current unit cost ratio used by MOPH.

4.5.3 Economies of scale & scope

The identification of diseconomies of scale among community and provincial hospitals implies that the hospitals are generally too large. Interestingly the provincial hospitals have less diseconomies of scale than community hospitals. This finding suggests that the public hospitals, particularly the community hospitals, may reduce their sizes and be broken-down to a larger numbers of smaller hospitals.

Whilst there are roughly one community and provincial hospital for each district and province, it may be suggested to increase the number of hospitals per district/province through down-sizing. However, such down-sizing should not be excessive since it could result in decreasing returns to scale. Furthermore, if such breaking-down of hospitals would result in an overall increase of outputs due to, for instance, the changes in health seeking behaviours of the population, diseconomies of scale would persist.

The finding of potential economies of scope, even though with some remaining uncertainties due to the unknown optimal level of capital stock, may have another implication on the above discussion on scale economies. Whilst the outpatient volume has little impact on the cost of inpatient services, down-sizing of outpatient department may be advocated since it has little effect on the unit cost of inpatient services. However, establishing a stand-alone clinic to make-up for the excess demand would result in an increase of outpatient unit cost. Therefore the benefit and loss from scope economies must be carefully weighted against the loss and benefit from scale economies in making decisions on the size of hospitals. It should also be weighted against the benefit of improved access to healthcare by separating some portions of hospitals and locating then in distant areas. Discussing the optimal size, service mix and placement of facilities, however, would require further investigations on hospital efficiencies which are well beyond the scope of this study.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As has been demonstrated in this paper, econometric techniques and analyses can provide insights to the cost structure and characteristics of public hospitals in Thailand. Even though some difficulties remain in analysing the true nature of costs of hospitals, the estimated models were generally satisfactory, and valuable implications were derived from this study for policy and decision-makings. The following summarises the major findings.

(1) The hospital cost structure can be described by a short-run flexible function.

Translog function, which is widely used in empirical studies on cost structure and characteristics of firms, could be successfully applied to the public hospitals in Thailand. However, the precondition of the cost-minimising level of capital for a long-run cost function favoured the employment of a short-run cost function. This implies that the capitals of public hospitals are not adjusted to the cost-minimising levels, or merely an insufficient quality of data for capitals. Perhaps both of these issues are present in this context, and so improvement in management and recording of capital data would be of primary importance.

It must be noted that an important property of a translog function is its nature of local approximation of a true cost function, which implies that one cannot use the same function to describe the cost structure and characteristics for a wide range of hospitals in size and volume of outputs which is sufficiently apart from an average hospital. This property limits the application of the functional model to a relatively narrow range of hospitals. Nonetheless the translog function can analyse various policy questions useful for decision makings and hence its application was justified.

(2) *Inpatient services and input factors, except for medical doctors, are the main determinants of hospital costs.*

In terms of outputs, the number of inpatient admissions was identified as the major determinant factor of hospital costs. Average length of stay, which represents the bed-day component of inpatient services, also has a significant influence on the level and mix of resources used, and so it affects the hospital costs in an indirect manner.

In terms of inputs, both labour and material prices are the major factors determining the hospital costs. Medical doctors, however, were not identified as having a significant impact on hospital costs. This is possibly due to the large variance of wage levels among junior and senior personnel, which do not necessarily correlate with the level of hospital costs.

(3) *Unit cost may be estimated econometrically by using the cost ratio concept. However, it requires a large sample size to develop an accurate regression model.*

Econometric estimation of unit costs requires two steps in its model. The first step is to isolate the cost devoted to patient services from the total cost of hospitals. The second step is to divide the full cost of patient services into inpatient and outpatient unit costs at a certain ratio. It was revealed that the estimated ratio for an average-sized community hospital provides a similar result to the current practice of MOPH. On the other hand, the estimated ratio for an average provincial hospital is significantly different from the current MOPH practice. In any case, the relatively large estimation errors encountered by some sample hospitals pose a question whether this estimated model could be used in real practice. Perhaps the main difficulty in developing an econometric model like this is that the accurate unit cost estimated through accounting exercises require special studies and hence is not routinely available. Larger sample size and standardised accounting-based estimations would significantly improve the accuracy of this model.

(4) Diseconomies of scale was identified among public hospitals in Thailand

The identification of diseconomies of scale suggests that the current community and provincial hospitals could potentially improve their efficiencies by breaking-down to smaller sized facilities. One may recommend that the down-sizing of outpatient department of hospitals and establishing stand-alone clinics may bring down the average costs of both inpatient and outpatient services, and could also improve the accessibility for healthcare services for patients who reside in distance from the hospitals. However, the identification of partial economies of scope, even though with some uncertainties, suggests the opposite direction and so it is not straightforward to make recommendations for the size and service mix of hospitals.

(5) The universal coverage scheme (UC) is indeed one of hospitals' cost escalation factors.

The UC outpatient services were identified as being positively correlated with the hospital cost. Perhaps the escalating demand for healthcare far exceeds the cost containment incentives imposed on the hospital side through the capitation-based payment mechanism. On the other hand, the UC inpatient services had the opposite sign even though its degree of influence was statistically insignificant. These results may suggest that the outpatient visits may be difficult to control which largely depend on patients' behaviours, whilst inpatient can still be controlled, if not significant, under the doctors' discretions. It is far from straight forward to strike the balance between accessibility to healthcare and cost containment of hospitals. However, some measures may be necessary to control the demand side factors should cost escalation of healthcare be contained for the sustainability of the UC scheme.

5.2 Recommendations

Out from the findings of this study, some policy implications and recommendations can be derived:

(1) The efficiency of community and provincial hospitals should be studied

Probably the efficiency of hospitals in each category could potentially be improved through down-sizing, if it does not result in an overall increase of output level. If the down-sizing takes place by breaking-down the individual facilities, and if such practices result in an increased number of hospitals in the locality, it would add another benefit of improved access to healthcare of the population. However, it should not compromise the potential benefit of efficiency gains by providing both inpatient and outpatient services in the same facility. Therefore, the optimum size and service mix which maximises the efficiency of public hospitals should be investigated by applying other methodologies such as stochastic frontier or data envelopment analyses.

(2) *Country-wide accounting-based unit cost studies should be conducted in a standardised manner even for a limited timeframe*

The development of an accurate econometric model to estimate the unit costs of hospitals could significantly speed-up various decision-making processes. The major limitation of this study was the limited availability of data on accurate unit costs and their corresponding characteristics of hospitals. If a standardised study can be conducted for a fairly large sample size, even for a limited timeframe, the data would provide more insights to unit cost characteristics. It should be noted that the relevant information should also be collected which would be used as different explanatory variables.

(3) *The UC must introduce some measures to control the excess demand particularly for outpatient services*

Whilst the UC outpatient was identified as one of the factors for cost escalation of hospitals, some measures should be introduced to control the demand. First of all, some financial incentives should be introduced such as co-payment or co-financing. However, the effectiveness of such financial mechanisms depends on elasticities of demand with respect to price of health care, which requires a major population-wide research to identify the effective level of payments. Therefore it may be difficult to design an efficient system in the first instance. In this connection, it would be suggested that such demand control based on financial incentives be combined with other non-financial measures (such as through waiting-time). Major studies on demand for health care among UC patients would be highly recommended.

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APPENDICES

LIST OF APPENDICES

Summary of reviewed literature

	Lave *et al*. (1972)	Li & Rosenman (2001)	Cowing & Holtman (1983)
Functional form used	Ad hoc	Generalised Leontief	Translog
Sample size	65 (1968) + 47 (1967), USA	90 x 6 years (1988-1993), USA	138 (1975), USA
Short-run / long-run	NA	Long-run	Short-run
# of outputs/inputs	17 / 0	2 / 11	5 / 5
# of parameters	33	186	107
Output-input price interaction	No	Yes	Yes
Case-mix adjusted	Yes (surgical difficulty index)	Yes (case-mix index)	No
Estimation procedure	Not clear	Feasible GLS	Maximum-likelihood
Cost share equation	NA	Not included	Included
Findings	- Complexity of case-mix is related to higher average cost - Teaching hospitals have negative correlation with costs, which may be due to students' services provided at low labour costs - Insurance was not significantly correlated with costs	- Core inpatient services and other intermediate outputs have positive elasticities: they are substitutes - Core inpatient services are complements to outpatient services - DRG based inpatient service has a negative sign	- The "positive" sign of capital implies an excessive over- capitalisation - Flexible substitutability identified among labour inputs, particularly with nurses and others
Economies of scale / scope	Scale: Insignificant Scope: NA	Scale: Yes Scope: Inconclusive	Scale: Yes Scope: Mixed results
Policy implications	NA (cost function proposed to be used for estimating the cost for an incentive reimbursement plan for non-government hospitals)	- Increase of stand-alone outpatient clinics may increase the cost of providing health care services - DRG helps to contain costs	- The finding support the policy of some states like New York to close down hospitals and concentrate in fewer hospitals - However, the mixed scope effects favour more specialised hospitals

	Conrad & Strauss (1983)	Vita (1990)	Hansen & Zwanziger (1996)
Functional form used	Translog	Generalised Translog	Quadratic
Sample size	114 (1978), USA	296 (1983), USA	USA (California): 394 (1981), 383 (1985) USA (New York): 185 (1981), 180 (1985) Canada: 271 (1981), 269 (1985)
Short-run / long-run	Long-run	Short-run	Long-run
# of outputs/inputs	3 / 4	9 / 6	4 / 1
# of parameters	36	98	California and New York: 25; Canada: 24
Output-input price interaction	Yes	Yes	Yes
Case-mix adjusted	No	Yes (case-mix index)	No
Estimation procedure	SURE	Maximum-likelihood	OLS-GLS
Cost share equation	Included	Included	Not included
Findings	- Nursing services are substitutes for ancillary and general services, but are complementary with capitals - Capitals and ancillary services are complements - Marginal cost for Medicare inpatient is lower than non-Medicare patient day	- All first-order outputs have positive signs, and most of them are significant - All inputs' own-price elasticities of factor demands are negative - The cost behaviour for output levels outside the neighbourhood region of approximation point is not accurately estimated	Marginal costs were significantly higher for California and New York than for Canada, which imply different resource use intensities between the countries
Economies of scale / scope	NA	Scale: Diseconomies of scale Scope: Insignificant	Scale: New York: Insignificant California: Mixed results Canada: Mixed results Scope: NA
Policy implications	Complementary nature of nurses, technicians, and other specialised labours with capitals explains the escalation of cost with the introduction of high-technology capitals	The flexible cost functions cannot provide credible answers to policy questions which involve large, discrete changes in outputs such as mergers or consolidations of hospitals	NA

	Grannemann *et al*. (1986)	Weaver & Deolalikar (2004)	Aletres (1999)
Functional form used	Hybrid	Hybrid	Hybrid translog
Sample size	867 (1981), USA	597 (1996), Vietnam	94 (1992), Greece
Short-run / long-run	Long-run	Short-run	Long-run & Short-run
# of outputs/inputs	14 / 4	4 / 0	2 / 0
# of parameters	64	27	Long-run: 8; Short-run: 12
Output-input price interaction	No	NA	Yes
Case-mix adjusted	Yes (% of Medicaid patients)	Yes (Roemer's case-mix index)	Yes (Roemer's case-mix index)
Estimation procedure	OLS	OLS	OLS
Cost share equation	Not included	Not included	Not included
Findings	- Approx. 65% of marginal cost accounts for day costs while 35% for discharge cost, which suggest that shortening of average length of stay may result in substantial cost savings - High proportion of <45 years medical staff are significantly more costly than those with older staff	- Cost levels significantly differ across regions and levels of hospitals - Recent hospital reforms such as the introduction of social insurance or staff bonus system had no significant effects on the cost of hospitals	- Long-run cost function was favoured since the capital was not in the long-run equilibrium - In both long-run and short-run, the translog specification was rejected and the Cobb-Douglas model was favoured
Economies of scale / scope	Scale: Yes for emergency care Scope: Diseconomies of scope between inpatient and outpatient services	Scale: Central: Negligible Provincial: Diseconomies of scale District: Yes Scope: Yes	Scale: Insignificant Scope: NA
Policy implications	A fixed payment for discharges and fixed payment per bed-day could bring the reimbursement closer to the marginal cost	- Optimum size of hospitals depends on the category of hospitals - Increasing inpatient and outpatient cases with the current capacity will improve efficiency	The prospective reimbursement rate for hospitals should not account for scale economies

Appendix B: Eviews' estimation for the long-run cost function (rejected)

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 4224
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 15 weight matrices, 16 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	1.820454	0.424015	4.293375	0.0000
C(21)	0.459560	0.077313	5.944128	0.0000
C(22)	0.369781	0.118472	3.121251	0.0018
C(23)	-0.099653	0.146017	-0.682476	0.4950
C(211)	0.075997	0.011609	6.546178	0.0000
C(222)	0.155895	0.019104	8.160250	0.0000
C(233)	0.019450	0.027590	0.704954	0.4809
C(212)	-0.108124	0.013610	-7.944263	0.0000
C(213)	0.055932	0.016907	3.308223	0.0009
C(223)	-0.057093	0.021739	-2.626230	0.0087
C(31)	-0.027847	0.011817	-2.356639	0.0185
C(32)	0.180322	0.039374	4.579689	0.0000
C(33)	0.056739	0.021000	2.701930	0.0069
C(34)	0.060710	0.010464	5.801954	0.0000
C(36)	0.075658	0.022017	3.436269	0.0006
C(311)	0.011790	0.002046	5.763173	0.0000
C(322)	0.157363	0.010660	14.76149	0.0000
C(333)	0.090388	0.007383	12.24236	0.0000
C(344)	0.010875	0.002457	4.426794	0.0000
C(312)	-0.011111	0.003467	-3.204322	0.0014
C(313)	0.002849	0.002714	1.049567	0.2940
C(314)	0.004674	0.001506	3.103440	0.0019
C(316)	0.001598	0.000829	1.928214	0.0539
C(323)	-0.043421	0.007645	-5.679894	0.0000
C(324)	-0.006326	0.003720	-1.700818	0.0891
C(326)	-0.010377	0.002105	-4.930034	0.0000
C(334)	7.41E-05	0.003021	0.024522	0.9804
C(336)	-0.013970	0.001626	-8.592734	0.0000
C(346)	-0.000199	0.000724	-0.274666	0.7836
C(356)	-0.032775	0.001097	-29.87847	0.0000
C(366)	0.040793	0.001685	24.21290	0.0000
C(411)	0.008149	0.001292	6.308434	0.0000
C(412)	-0.005784	0.001657	-3.491046	0.0005
C(413)	0.013505	0.002352	5.740827	0.0000
C(421)	0.027228	0.004371	6.229698	0.0000
C(422)	-0.046563	0.005735	-8.119563	0.0000
C(423)	0.073590	0.008266	8.903169	0.0000
C(431)	0.003636	0.002291	1.587409	0.1125
C(432)	-0.023101	0.002926	-7.895161	0.0000
C(433)	0.003708	0.004176	0.888125	0.3745
C(441)	0.001227	0.001123	1.092252	0.2748
C(442)	-0.007896	0.001435	-5.501229	0.0000
C(443)	0.010159	0.002034	4.993709	0.0000
C(461)	0.016873	0.002409	7.005376	0.0000
C(462)	-0.027291	0.003209	-8.503841	0.0000
C(463)	0.021649	0.004769	4.539715	0.0000
C(81)	0.002938	0.016773	0.175189	0.8609
C(82)	-0.000364	0.000211	-1.726528	0.0843
C(83)	0.000632	0.000206	3.071412	0.0021

C(91)	-0.013601	0.004286	-3.173316	0.0015
C(92)	-0.003683	0.004206	-0.875697	0.3812
C(93)	0.003177	0.004279	0.742317	0.4579
C(94)	-0.016207	0.008104	-1.999857	0.0456

Determinant residual covariance	1.58E-20

Equation: LOG(TC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+0.5
*C(233)*LOG(LOS)^2+C(212)*LOG(IPD)*LOG(OPD)+C(213)*LOG(IPD)
*LOG(LOS)+C(223)*LOG(OPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)
*LOG(RN)+C(33)*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)
-C(33)-C(34)-C(36))*LOG(MAT)+C(36)*LOG(CAP)+0.5*C(311)
*LOG(MD)^2+0.5*C(322)*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5
*C(344)*LOG(NMED)^2+0.5*(0+C(311)+C(312)+C(313)+C(314)
+C(316)+C(312)+C(322)+C(323)+C(324)+C(326)+C(313)+C(323)
+C(333)+C(334)+C(336)+C(314)+C(324)+C(334)+C(344)+C(346)
+C(316)+C(326)+C(336)+C(346)+C(366))*LOG(MAT)^2+0.5*C(366)
*LOG(CAP)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314)-C(316))*LOG(MD)*LOG(MAT)+C(316)*LOG(MD)*LOG(CAP)
+C(323)*LOG(RN)*LOG(MED)+C(324)*LOG(RN)*LOG(NMED)+(0
-C(312)-C(322)-C(323)-C(324)-C(326))*LOG(RN)*LOG(MAT)+C(326)
*LOG(RN)*LOG(CAP)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)
-C(323)-C(333)-C(334)-C(336))*LOG(MED)*LOG(MAT)+C(336)
*LOG(MED)*LOG(CAP)+(0-C(314)-C(324)-C(334)-C(344)-C(346))
*LOG(NMED)*LOG(MAT)+C(346)*LOG(NMED)*LOG(CAP)+(0-C(316)
-C(326)-C(336)-C(346)-C(366))*LOG(MAT)*LOG(CAP)+C(411)
*LOG(MD)*LOG(IPD)+C(412)*LOG(MD)*LOG(OPD)+C(413)*LOG(MD)
*LOG(LOS)+C(421)*LOG(RN)*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)
+C(423)*LOG(RN)*LOG(LOS)+C(431)*LOG(MED)*LOG(IPD)+C(432)
*LOG(MED)*LOG(OPD)+C(433)*LOG(MED)*LOG(LOS)+C(441)
*LOG(NMED)*LOG(IPD)+C(442)*LOG(NMED)*LOG(OPD)+C(443)
*LOG(NMED)*LOG(LOS)+(0-C(411)-C(421)-C(431)-C(441)-C(461))
*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)-C(432)-C(442)-C(462))
*LOG(MAT)*LOG(OPD)+(0-C(413)-C(423)-C(433)-C(443)-C(463))
*LOG(MAT)*LOG(LOS)+C(461)*LOG(CAP)*LOG(IPD)+C(462)
*LOG(CAP)*LOG(OPD)+C(463)*LOG(CAP)*LOG(LOS)+C(81)*CM
+C(82)*IPUC+C(83)*OPUC+C(91)*LOC1+C(92)*LOC2+C(93)*LOC3
+C(94)*LEV

Observations: 704

R-squared	0.981523	Mean dependent var	18.20325
Adjusted R-squared	0.980078	S.D. dependent var	0.954017
S.E. of regression	0.134656	Sum squared resid	11.82223
Durbin-Watson stat	1.249989		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314)
-C(316))*LOG(MAT)+C(316)*LOG(CAP)+C(411)*LOG(IPD)+C(412)
*LOG(OPD)+C(413)*LOG(LOS)

Observations: 704

R-squared	0.187795	Mean dependent var	0.030506
Adjusted R-squared	0.178446	S.D. dependent var	0.013914
S.E. of regression	0.012612	Sum squared resid	0.110542
Durbin-Watson stat	1.721775		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324)
-C(326))*LOG(MAT)+C(326)*LOG(CAP)+C(421)*LOG(IPD)+C(422)
*LOG(OPD)+C(423)*LOG(LOS)

Observations: 704

R-squared	0.345122	Mean dependent var	0.296171
Adjusted R-squared	0.337584	S.D. dependent var	0.061798
S.E. of regression	0.050297	Sum squared resid	1.758206
Durbin-Watson stat	1.198445		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344)
-C(346))*LOG(MAT)+C(346)*LOG(CAP)+C(441)*LOG(IPD)+C(442)
*LOG(OPD)+C(443)*LOG(LOS)

Observations: 704

R-squared	0.269155	Mean dependent var	0.028393
Adjusted R-squared	0.260742	S.D. dependent var	0.012569
S.E. of regression	0.010807	Sum squared resid	0.081164
Durbin-Watson stat	1.710891		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34)-C(36))+(0+C(311)+C(312)
+C(313)+C(314)+C(316)+C(312)+C(322)+C(323)+C(324)+C(326)
+C(313)+C(323)+C(333)+C(334)+C(336)+C(314)+C(324)+C(334)
+C(344)+C(346)+C(316)+C(326)+C(336)+C(346)+C(366))*LOG(MAT)
+(0-C(311)-C(312)-C(313)-C(314)-C(316))*LOG(MD)+(0-C(312)
-C(322)-C(323)-C(324)-C(326))*LOG(RN)+(0-C(313)-C(323)-C(333)
-C(334)-C(336))*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344)-C(346))
*LOG(NMED)+C(356)*LOG(CAP)+(0-C(411)-C(421)-C(431)-C(441)
-C(461))*LOG(IPD)+(0-C(412)-C(422)-C(432)-C(442)-C(462))
*LOG(OPD)+(0-C(413)-C(423)-C(433)-C(443)-C(463))*LOG(LOS)

Observations: 704

R-squared	0.633828	Mean dependent var	0.479340
Adjusted R-squared	0.614642	S.D. dependent var	0.099528
S.E. of regression	0.061784	Sum squared resid	2.549932
Durbin-Watson stat	1.219726		

Equation: SCAP=C(36)+C(366)*LOG(CAP)+C(316)*LOG(MD)+C(326)
*LOG(RN)+C(336)*LOG(MED)+C(346)*LOG(NMED)+(0-C(316)-C(326)
-C(336)-C(346)-C(366))*LOG(MAT)+C(461)*LOG(IPD)+C(462)
*LOG(OPD)+C(463)*LOG(LOS)

Observations: 704

R-squared	0.524412	Mean dependent var	0.058225
Adjusted R-squared	0.518937	S.D. dependent var	0.040689
S.E. of regression	0.028221	Sum squared resid	0.553528
Durbin-Watson stat	1.900859		

Parameters:
- C(10): α = constant
- C(2**): β = output
- C(3**): γ = input price
- C(4**): δ = input-output interaction
- C(8**): η = other factor
- C(9**): φ = dummy

Omitted cost share equation:

SMED=c(33)+c(333)*Log(MED)+c(313)*Log(MD)+c(323)*Log(RN)+c(334)*Log(NMED)
+c(335)*Log(MAT)+c(336)*Log(CAP)+c(431)*Log(IPD)+c(432)*Log(OPD)+c(433)*Log(LOS)

NB: The negative signs for c(23) and c(31) contradict with the pre-conditions for a cost function (a non-decreasing function in outputs and input prices).

Appendix C: Eviews' estimation for the short-run cost function (initial regression run) and testing for the omission of other factors

Initial regression run

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 15 weight matrices, 16 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.310205	0.501053	4.610698	0.0000
C(21)	0.294841	0.086954	3.390759	0.0007
C(22)	0.170385	0.128058	1.330533	0.1834
C(23)	0.062586	0.169271	0.369737	0.7116
C(211)	0.037895	0.014821	2.556749	0.0106
C(222)	0.162951	0.018861	8.639529	0.0000
C(233)	-0.006802	0.028322	-0.240166	0.8102
C(212)	-0.054367	0.014024	-3.876709	0.0001
C(213)	0.025743	0.019823	1.298671	0.1941
C(223)	-0.051676	0.021447	-2.409525	0.0160
C(31)	0.009269	0.013363	0.693653	0.4879
C(32)	0.363061	0.043675	8.312717	0.0000
C(33)	0.189885	0.023566	8.057549	0.0000
C(34)	0.083070	0.011629	7.143405	0.0000
C(311)	0.013489	0.002220	6.076239	0.0000
C(322)	0.200252	0.011408	17.55333	0.0000
C(333)	0.096191	0.007873	12.21800	0.0000
C(344)	0.012159	0.002646	4.595892	0.0000
C(312)	-0.009257	0.003767	-2.457083	0.0141
C(313)	0.004429	0.002908	1.523099	0.1278
C(314)	0.005300	0.001624	3.263072	0.0011
C(323)	-0.044848	0.008260	-5.429481	0.0000
C(324)	-0.005131	0.004031	-1.272875	0.2031
C(334)	0.001442	0.003246	0.444322	0.6568
C(411)	0.004522	0.001649	2.741946	0.0061
C(412)	-0.010151	0.001817	-5.587667	0.0000
C(413)	0.011332	0.002705	4.188576	0.0000
C(421)	0.000721	0.005383	0.133886	0.8935
C(422)	-0.087213	0.005878	-14.83657	0.0000
C(423)	0.064732	0.008824	7.336133	0.0000
C(431)	0.006451	0.002904	2.221336	0.0264
C(432)	-0.034836	0.003200	-10.88745	0.0000
C(433)	0.015065	0.004730	3.185053	0.0015
C(441)	-0.000987	0.001417	-0.696813	0.4860
C(442)	-0.011794	0.001568	-7.521545	0.0000
C(443)	0.009833	0.002321	4.236523	0.0000
C(51)	0.373289	0.084155	4.435741	0.0000
C(511)	0.061038	0.012436	4.908137	0.0000
C(611)	0.008504	0.001470	5.784618	0.0000
C(621)	0.076049	0.004874	15.60384	0.0000
C(631)	0.009116	0.002593	3.516226	0.0004
C(641)	0.006164	0.001266	4.870420	0.0000
C(711)	0.004324	0.010171	0.425121	0.6708
C(712)	-0.076682	0.011179	-6.859430	0.0000
C(713)	0.036454	0.018335	1.988253	0.0469
C(81)	0.009463	0.015762	0.600390	0.5483

C(82)	-0.000121	0.000198	-0.612919	0.5400
C(83)	0.000702	0.000194	3.625657	0.0003
C(91)	-0.011766	0.004048	-2.906535	0.0037
C(92)	-0.010219	0.003933	-2.598614	0.0094
C(93)	-0.006683	0.003987	-1.676224	0.0938
C(94)	-0.035727	0.009264	-3.856655	0.0001

Determinant residual covariance	3.31E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+0.5
*C(233)*LOG(LOS)^2+C(212)*LOG(IPD)*LOG(OPD)+C(213)*LOG(IPD)
*LOG(LOS)+C(223)*LOG(OPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)
*LOG(RN)+C(33)*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)
-C(33)-C(34))*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)
*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5
*(0+C(311)+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)
+C(313)+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)
*LOG(MD)*LOG(OPD)+C(413)*LOG(MD)*LOG(LOS)+C(421)*LOG(RN)
*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)+C(423)*LOG(RN)*LOG(LOS)
+C(431)*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)*LOG(OPD)+C(433)
*LOG(MED)*LOG(LOS)+C(441)*LOG(NMED)*LOG(IPD)+C(442)
*LOG(NMED)*LOG(OPD)+C(443)*LOG(NMED)*LOG(LOS)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)
-C(432)-C(442))*LOG(MAT)*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(MAT)*LOG(LOS)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)*LOG(OPD)+C(713)
*LOG(BED)*LOG(LOS)+C(81)*CM+C(82)*IPUC+C(83)*OPUC+C(91)
*LOC1+C(92)*LOC2+C(93)*LOC3+C(94)*LEV

Observations: 704

R-squared	0.978900	Mean dependent var	18.14215
Adjusted R-squared	0.977250	S.D. dependent var	0.962925
S.E. of regression	0.145239	Sum squared resid	13.75354
Durbin-Watson stat	1.396659		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)
+C(413)*LOG(LOS)

Observations: 704

R-squared	0.209680	Mean dependent var	0.032518
Adjusted R-squared	0.200583	S.D. dependent var	0.015180
S.E. of regression	0.013573	Sum squared resid	0.128030
Durbin-Watson stat	1.723849		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)
+C(423)*LOG(LOS)

Observations: 704

R-squared	0.400012	Mean dependent var	0.315047
Adjusted R-squared	0.393106	S.D. dependent var	0.066967
S.E. of regression	0.052170	Sum squared resid	1.891562
Durbin-Watson stat	1.314214		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)
+C(443)*LOG(LOS)
Observations: 704

R-squared	0.294860	Mean dependent var	0.030270
Adjusted R-squared	0.286743	S.D. dependent var	0.013749
S.E. of regression	0.011612	Sum squared resid	0.093707
Durbin-Watson stat	1.708665		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(LOS)
Observations: 704

R-squared	0.582400	Mean dependent var	0.507872
Adjusted R-squared	0.564432	S.D. dependent var	0.098438
S.E. of regression	0.064966	Sum squared resid	2.844712
Durbin-Watson stat	1.373901		

Parameters:	C(10):	α = constant
	C(2**):	β = output
	C(3**):	γ = input price
	C(4**):	δ = input-output interaction
	C(5**):	κ= capital
	C(6**):	τ = capital-input interaction
	C(7**):	π = capital-output interaction
	C(8**):	η= other factor
	C(9**):	φ = dummy

Omitted cost share equation:

SMED=c(33)+c(333)*Log(MED)+c(313)*Log(MD)+c(323)*Log(RN)
+c(334)*Log(NMED)+(0-c(313)-c(323)-c(333)-c(334))*Log(MAT)
+c(631)*Log(BED)+c(431)*Log(IPD)+c(432)*Log(OPD)+c(433)*Log(LOS)

NB: Even though not included in this Appendix, two alternative regressions were run to recover the information for parameters which were missing due to impositions of restrictions.

Omission of CM

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 15 weight matrices, 16 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.321719	0.500822	4.635821	0.0000
C(21)	0.292922	0.086897	3.370911	0.0008
C(22)	0.170996	0.128048	1.335401	0.1818
C(23)	0.059801	0.169225	0.353382	0.7238
C(211)	0.037604	0.014812	2.538703	0.0112
C(222)	0.162901	0.018861	8.636924	0.0000
C(233)	-0.006772	0.028322	-0.239118	0.8110
C(212)	-0.054221	0.014022	-3.866872	0.0001
C(213)	0.025932	0.019821	1.308322	0.1909
C(223)	-0.051411	0.021443	-2.397504	0.0166
C(31)	0.009271	0.013363	0.693783	0.4879
C(32)	0.363493	0.043668	8.324029	0.0000
C(33)	0.190082	0.023563	8.066857	0.0000
C(34)	0.082996	0.011629	7.136739	0.0000
C(311)	0.013480	0.002220	6.073034	0.0000
C(322)	0.200332	0.011407	17.56203	0.0000
C(333)	0.096162	0.007874	12.21293	0.0000
C(344)	0.012168	0.002646	4.599317	0.0000
C(312)	-0.009249	0.003767	-2.455175	0.0141
C(313)	0.004448	0.002908	1.529569	0.1262
C(314)	0.005299	0.001624	3.262573	0.0011
C(323)	-0.044853	0.008261	-5.429695	0.0000
C(324)	-0.005119	0.004031	-1.269778	0.2042
C(334)	0.001448	0.003246	0.446192	0.6555
C(411)	0.004528	0.001649	2.745520	0.0061
C(412)	-0.010164	0.001817	-5.595400	0.0000
C(413)	0.011341	0.002705	4.192191	0.0000
C(421)	0.000730	0.005383	0.135691	0.8921
C(422)	-0.087304	0.005877	-14.85640	0.0000
C(423)	0.064727	0.008824	7.334943	0.0000
C(431)	0.006438	0.002904	2.216842	0.0267
C(432)	-0.034837	0.003199	-10.88894	0.0000
C(433)	0.015029	0.004729	3.177776	0.0015
C(441)	-0.000981	0.001417	-0.692643	0.4886
C(442)	-0.011805	0.001568	-7.528375	0.0000
C(443)	0.009837	0.002321	4.237987	0.0000
C(51)	0.371218	0.084082	4.414967	0.0000
C(511)	0.060948	0.012435	4.901351	0.0000
C(611)	0.008508	0.001470	5.787420	0.0000
C(621)	0.076086	0.004874	15.61092	0.0000
C(631)	0.009119	0.002592	3.517427	0.0004
C(641)	0.006174	0.001266	4.877844	0.0000
C(711)	0.004862	0.010126	0.480147	0.6312
C(712)	-0.076837	0.011175	-6.875493	0.0000
C(713)	0.036270	0.018333	1.978398	0.0480
C(82)	-0.000108	0.000197	-0.549868	0.5824
C(83)	0.000698	0.000193	3.606843	0.0003
C(91)	-0.011496	0.004031	-2.852233	0.0044
C(92)	-0.009907	0.003906	-2.536505	0.0112
C(93)	-0.007075	0.003926	-1.802028	0.0716
C(94)	-0.035438	0.009244	-3.833391	0.0001

Determinant residual covariance	3.31E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+0.5
*C(233)*LOG(LOS)^2+C(212)*LOG(IPD)*LOG(OPD)+C(213)*LOG(IPD)
*LOG(LOS)+C(223)*LOG(OPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)
*LOG(RN)+C(33)*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)
-C(33)-C(34))*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)
*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5
*(0+C(311)+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)
+C(313)+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)
*LOG(MD)*LOG(OPD)+C(413)*LOG(MD)*LOG(LOS)+C(421)*LOG(RN)
*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)+C(423)*LOG(RN)*LOG(LOS)
+C(431)*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)*LOG(OPD)+C(433)
*LOG(MED)*LOG(LOS)+C(441)*LOG(NMED)*LOG(IPD)+C(442)
*LOG(NMED)*LOG(OPD)+C(443)*LOG(NMED)*LOG(LOS)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)
-C(432)-C(442))*LOG(MAT)*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(MAT)*LOG(LOS)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)*LOG(OPD)+C(713)
*LOG(BED)*LOG(LOS)+C(82)*IPUC+C(83)*OPUC+C(91)*LOC1+C(92)
*LOC2+C(93)*LOC3+C(94)*LEV

Observations: 704

R-squared	0.978884	Mean dependent var	18.14215
Adjusted R-squared	0.977267	S.D. dependent var	0.962925
S.E. of regression	0.145184	Sum squared resid	13.76428
Durbin-Watson stat	1.395900		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)
+C(413)*LOG(LOS)

Observations: 704

R-squared	0.209628	Mean dependent var	0.032518
Adjusted R-squared	0.200530	S.D. dependent var	0.015180
S.E. of regression	0.013573	Sum squared resid	0.128038
Durbin-Watson stat	1.723822		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)
+C(423)*LOG(LOS)

Observations: 704

R-squared	0.399747	Mean dependent var	0.315047
Adjusted R-squared	0.392837	S.D. dependent var	0.066967
S.E. of regression	0.052181	Sum squared resid	1.892399
Durbin-Watson stat	1.314027		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)

*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)
+C(443)*LOG(LOS)
Observations: 704

R-squared	0.294698	Mean dependent var	0.030270
Adjusted R-squared	0.286579	S.D. dependent var	0.013749
S.E. of regression	0.011613	Sum squared resid	0.093728
Durbin-Watson stat	1.708556		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(LOS)
Observations: 704

R-squared	0.582150	Mean dependent var	0.507872
Adjusted R-squared	0.564172	S.D. dependent var	0.098438
S.E. of regression	0.064986	Sum squared resid	2.846413
Durbin-Watson stat	1.373564		

Omission of UCIP

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 14 weight matrices, 15 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.325475	0.500704	4.644409	0.0000
C(21)	0.293888	0.086916	3.381281	0.0007
C(22)	0.167401	0.128025	1.307567	0.1911
C(23)	0.067647	0.169133	0.399966	0.6892
C(211)	0.037331	0.014796	2.522964	0.0117
C(222)	0.163010	0.018862	8.642304	0.0000
C(233)	-0.005911	0.028273	-0.209078	0.8344
C(212)	-0.053919	0.013999	-3.851570	0.0001
C(213)	0.026724	0.019771	1.351723	0.1766
C(223)	-0.052873	0.021383	-2.472613	0.0135
C(31)	0.009279	0.013363	0.694342	0.4875
C(32)	0.362757	0.043684	8.304101	0.0000
C(33)	0.190033	0.023564	8.064475	0.0000
C(34)	0.083128	0.011629	7.148420	0.0000
C(311)	0.013487	0.002220	6.075157	0.0000
C(322)	0.200313	0.011408	17.55959	0.0000
C(333)	0.096144	0.007873	12.21138	0.0000
C(344)	0.012158	0.002646	4.595083	0.0000
C(312)	-0.009260	0.003767	-2.457874	0.0140
C(313)	0.004427	0.002908	1.522465	0.1280
C(314)	0.005301	0.001624	3.263371	0.0011
C(323)	-0.044824	0.008260	-5.426405	0.0000
C(324)	-0.005134	0.004032	-1.273460	0.2029
C(334)	0.001436	0.003246	0.442346	0.6583
C(411)	0.004511	0.001649	2.735270	0.0063

C(412)	-0.010144	0.001817	-5.583742	0.0000
C(413)	0.011311	0.002705	4.181458	0.0000
C(421)	0.000502	0.005371	0.093482	0.9255
C(422)	-0.087111	0.005876	-14.82407	0.0000
C(423)	0.064513	0.008813	7.320154	0.0000
C(431)	0.006373	0.002901	2.196564	0.0281
C(432)	-0.034791	0.003199	-10.87698	0.0000
C(433)	0.014952	0.004725	3.164236	0.0016
C(441)	-0.001004	0.001417	-0.708856	0.4785
C(442)	-0.011786	0.001568	-7.516400	0.0000
C(443)	0.009809	0.002321	4.227086	0.0000
C(51)	0.373755	0.084150	4.441511	0.0000
C(511)	0.060972	0.012436	4.902837	0.0000
C(611)	0.008516	0.001470	5.792848	0.0000
C(621)	0.076282	0.004859	15.69784	0.0000
C(631)	0.009177	0.002590	3.543249	0.0004
C(641)	0.006177	0.001265	4.881227	0.0000
C(711)	0.004394	0.010172	0.431952	0.6658
C(712)	-0.076819	0.011179	-6.871829	0.0000
C(713)	0.036457	0.018335	1.988316	0.0469
C(81)	0.008412	0.015661	0.537167	0.5912
C(83)	0.000617	0.000138	4.483317	0.0000
C(91)	-0.011813	0.004048	-2.918311	0.0035
C(92)	-0.010194	0.003933	-2.591932	0.0096
C(93)	-0.006880	0.003970	-1.733008	0.0832
C(94)	-0.035270	0.009245	-3.814846	0.0001

Determinant residual covariance	3.31E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+0.5
*C(233)*LOG(LOS)^2+C(212)*LOG(IPD)*LOG(OPD)+C(213)*LOG(IPD)
*LOG(LOS)+C(223)*LOG(OPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)
*LOG(RN)+C(33)*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)
-C(33)-C(34))*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)
*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5
*(0+C(311)+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)
+C(313)+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)
*LOG(MD)*LOG(OPD)+C(413)*LOG(MD)*LOG(LOS)+C(421)*LOG(RN)
*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)+C(423)*LOG(RN)*LOG(LOS)
+C(431)*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)*LOG(OPD)+C(433)
*LOG(MED)*LOG(LOS)+C(441)*LOG(NMED)*LOG(IPD)+C(442)
*LOG(NMED)*LOG(OPD)+C(443)*LOG(NMED)*LOG(LOS)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)
-C(432)-C(442))*LOG(MAT)*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(MAT)*LOG(LOS)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)*LOG(OPD)+C(713)
*LOG(BED)*LOG(LOS)+C(81)*CM+C(83)*OPUC+C(91)*LOC1+C(92)
*LOC2+C(93)*LOC3+C(94)*LEV

Observations: 704

R-squared	0.978932	Mean dependent var	18.14215
Adjusted R-squared	0.977319	S.D. dependent var	0.962925
S.E. of regression	0.145019	Sum squared resid	13.73295
Durbin-Watson stat	1.398669		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)
+C(413)*LOG(LOS)
Observations: 704

R-squared	0.209693	Mean dependent var	0.032518
Adjusted R-squared	0.200596	S.D. dependent var	0.015180
S.E. of regression	0.013572	Sum squared resid	0.128028
Durbin-Watson stat	1.723858		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)
+C(423)*LOG(LOS)
Observations: 704

R-squared	0.399636	Mean dependent var	0.315047
Adjusted R-squared	0.392726	S.D. dependent var	0.066967
S.E. of regression	0.052186	Sum squared resid	1.892748
Durbin-Watson stat	1.314925		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)
+C(443)*LOG(LOS)
Observations: 704

R-squared	0.294916	Mean dependent var	0.030270
Adjusted R-squared	0.286800	S.D. dependent var	0.013749
S.E. of regression	0.011611	Sum squared resid	0.093699
Durbin-Watson stat	1.708690		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(LOS)
Observations: 704

R-squared	0.582239	Mean dependent var	0.507872
Adjusted R-squared	0.564264	S.D. dependent var	0.098438
S.E. of regression	0.064979	Sum squared resid	2.845807
Durbin-Watson stat	1.374529		

Appendix D: Eviews' estimation for the short-run cost function (final)

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 14 weight matrices, 15 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.334342	0.500530	4.663743	0.0000
C(21)	0.292254	0.086868	3.364330	0.0008
C(22)	0.168242	0.128009	1.314301	0.1888
C(23)	0.064647	0.169064	0.382379	0.7022
C(211)	0.037124	0.014790	2.510055	0.0121
C(222)	0.162959	0.018862	8.639692	0.0000
C(233)	-0.005972	0.028273	-0.211217	0.8327
C(212)	-0.053831	0.013998	-3.845539	0.0001
C(213)	0.026798	0.019770	1.355479	0.1754
C(223)	-0.052517	0.021376	-2.456852	0.0141
C(31)	0.009279	0.013363	0.694398	0.4875
C(32)	0.363176	0.043674	8.315578	0.0000
C(33)	0.190195	0.023562	8.072186	0.0000
C(34)	0.083056	0.011629	7.141986	0.0000
C(311)	0.013480	0.002220	6.072421	0.0000
C(322)	0.200380	0.011407	17.56688	0.0000
C(333)	0.096124	0.007874	12.20751	0.0000
C(344)	0.012166	0.002646	4.598196	0.0000
C(312)	-0.009252	0.003767	-2.456104	0.0141
C(313)	0.004445	0.002908	1.528367	0.1265
C(314)	0.005300	0.001624	3.262869	0.0011
C(323)	-0.044831	0.008261	-5.426947	0.0000
C(324)	-0.005122	0.004032	-1.270578	0.2040
C(334)	0.001442	0.003246	0.444219	0.6569
C(411)	0.004517	0.001649	2.739199	0.0062
C(412)	-0.010156	0.001816	-5.591275	0.0000
C(413)	0.011322	0.002705	4.185535	0.0000
C(421)	0.000532	0.005371	0.099094	0.9211
C(422)	-0.087203	0.005874	-14.84622	0.0000
C(423)	0.064530	0.008814	7.321647	0.0000
C(431)	0.006369	0.002901	2.195113	0.0282
C(432)	-0.034796	0.003198	-10.87989	0.0000
C(433)	0.014930	0.004725	3.159902	0.0016
C(441)	-0.000997	0.001417	-0.703962	0.4815
C(442)	-0.011796	0.001568	-7.523196	0.0000
C(443)	0.009815	0.002321	4.229391	0.0000
C(51)	0.371846	0.084069	4.423097	0.0000
C(511)	0.060898	0.012435	4.897249	0.0000
C(611)	0.008518	0.001470	5.794576	0.0000
C(621)	0.076292	0.004860	15.69893	0.0000
C(631)	0.009173	0.002590	3.541925	0.0004
C(641)	0.006184	0.001265	4.886879	0.0000
C(711)	0.004871	0.010126	0.481022	0.6305
C(712)	-0.076944	0.011175	-6.885119	0.0000
C(713)	0.036290	0.018334	1.979445	0.0478
C(83)	0.000622	0.000137	4.526471	0.0000
C(91)	-0.011565	0.004029	-2.870372	0.0041
C(92)	-0.009915	0.003906	-2.538515	0.0112
C(93)	-0.007213	0.003915	-1.842335	0.0655

C(94)	-0.035054	0.009230	-3.797872	0.0001
Determinant residual covariance		3.31E-17		

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+0.5
*C(233)*LOG(LOS)^2+C(212)*LOG(IPD)*LOG(OPD)+C(213)*LOG(IPD)
*LOG(LOS)+C(223)*LOG(OPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)
*LOG(RN)+C(33)*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)
-C(33)-C(34))*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)
*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5
*(0+C(311)+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)
+C(313)+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)
*LOG(MD)*LOG(OPD)+C(413)*LOG(MD)*LOG(LOS)+C(421)*LOG(RN)
*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)+C(423)*LOG(RN)*LOG(LOS)
+C(431)*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)*LOG(OPD)+C(433)
*LOG(MED)*LOG(LOS)+C(441)*LOG(NMED)*LOG(IPD)+C(442)
*LOG(NMED)*LOG(OPD)+C(443)*LOG(NMED)*LOG(LOS)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)
-C(432)-C(442))*LOG(MAT)*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(MAT)*LOG(LOS)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)*LOG(OPD)+C(713)
*LOG(BED)*LOG(LOS)+C(83)*OPUC+C(91)*LOC1+C(92)*LOC2
+C(93)*LOC3+C(94)*LEV

Observations: 704

R-squared	0.978914	Mean dependent var	18.14215
Adjusted R-squared	0.977334	S.D. dependent var	0.962925
S.E. of regression	0.144970	Sum squared resid	13.74461
Durbin-Watson stat	1.397797		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)
+C(413)*LOG(LOS)

Observations: 704

R-squared	0.209644	Mean dependent var	0.032518
Adjusted R-squared	0.200547	S.D. dependent var	0.015180
S.E. of regression	0.013573	Sum squared resid	0.128035
Durbin-Watson stat	1.723833		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)
+C(423)*LOG(LOS)

Observations: 704

R-squared	0.399434	Mean dependent var	0.315047
Adjusted R-squared	0.392521	S.D. dependent var	0.066967
S.E. of regression	0.052195	Sum squared resid	1.893387
Durbin-Watson stat	1.314688		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)
+C(443)*LOG(LOS)
Observations: 704

R-squared	0.294765	Mean dependent var	0.030270
Adjusted R-squared	0.286647	S.D. dependent var	0.013749
S.E. of regression	0.011612	Sum squared resid	0.093719
Durbin-Watson stat	1.708590		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)+(0-C(413)-C(423)-C(433)
-C(443))*LOG(LOS)
Observations: 704

R-squared	0.582030	Mean dependent var	0.507872
Adjusted R-squared	0.564046	S.D. dependent var	0.098438
S.E. of regression	0.064995	Sum squared resid	2.847231
Durbin-Watson stat	1.374166		

Parameters:
- C(10): α = constant
- C(2**): β = output
- C(3**): γ = input price
- C(4**): δ = input-output interaction
- C(5**): κ= capital
- C(6**): τ = capital-input interaction
- C(7**): π = capital-output interaction
- C(8**): η= other factor
- C(9**): φ = dummy

Omitted cost share equation:

SMED=c(33)+c(333)*Log(MED)+c(313)*Log(MD)+c(323)*Log(RN)
+c(334)*Log(NMED)+(0-c(313)-c(323)-c(333)-c(334))*Log(MAT)
+c(631)*Log(BED)+c(431)*Log(IPD)+c(432)*Log(OPD)+c(433)*Log(LOS)

NB: Even though not included in this Appendix, two alternative regressions were run to recover the information for parameters which were missing due to impositions of restrictions.

Appendix E: Testing for the omission of outpatient variable

Omission of second-order variables

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 24 weight matrices, 25 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	0.735760	0.179806	4.091968	0.0000
C(21)	0.067239	0.054919	1.224326	0.2209
C(22)	0.955134	0.004753	200.9417	0.0000
C(23)	-0.353684	0.109450	-3.231461	0.0012
C(211)	0.021849	0.009799	2.229698	0.0258
C(233)	0.013407	0.030207	0.443848	0.6572
C(213)	0.017626	0.017481	1.008274	0.3134
C(31)	-0.056678	0.009413	-6.021135	0.0000
C(32)	-0.204592	0.028745	-7.117375	0.0000
C(33)	-0.028421	0.016615	-1.710538	0.0873
C(34)	0.003768	0.008431	0.446914	0.6550
C(311)	0.013858	0.002221	6.238657	0.0000
C(322)	0.198595	0.011199	17.73359	0.0000
C(333)	0.094756	0.007907	11.98430	0.0000
C(344)	0.012819	0.002637	4.861123	0.0000
C(312)	-0.010285	0.003735	-2.753481	0.0059
C(313)	0.004535	0.002915	1.555444	0.1199
C(314)	0.005565	0.001622	3.430251	0.0006
C(323)	-0.045727	0.008209	-5.570249	0.0000
C(324)	-0.005584	0.003987	-1.400663	0.1614
C(334)	0.001058	0.003249	0.325599	0.7447
C(411)	-0.000312	0.001352	-0.230930	0.8174
C(413)	0.009992	0.002698	3.702815	0.0002
C(421)	-0.039266	0.004656	-8.434231	0.0000
C(423)	0.053302	0.009240	5.768868	0.0000
C(431)	-0.010085	0.002439	-4.134482	0.0000
C(433)	0.010170	0.004838	2.102286	0.0356
C(441)	-0.006603	0.001175	-5.622176	0.0000
C(443)	0.008478	0.002347	3.612953	0.0003
C(51)	-0.094919	0.049489	-1.917970	0.0552
C(511)	0.048713	0.012958	3.759389	0.0002
C(611)	0.006863	0.001463	4.691979	0.0000
C(621)	0.060213	0.005020	11.99569	0.0000
C(631)	0.002946	0.002631	1.119730	0.2629
C(641)	0.004430	0.001275	3.475391	0.0005
C(711)	-0.028884	0.009689	-2.980977	0.0029
C(713)	0.011927	0.018589	0.641600	0.5212
C(83)	0.000815	0.000144	5.666106	0.0000
C(91)	-0.015366	0.004307	-3.567992	0.0004
C(92)	-0.008531	0.004177	-2.042517	0.0412
C(93)	-0.007106	0.004194	-1.694155	0.0903
C(94)	-0.044099	0.009674	-4.558578	0.0000

Determinant residual covariance 6.08E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(233)*LOG(LOS)^2+C(213)

*LOG(IPD)*LOG(LOS)+C(31)*LOG(MD)+C(32)*LOG(RN)+C(33)
*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)-C(33)-C(34))
*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)*LOG(RN)^2+0.5
*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5*(0+C(311)
+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)
+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(413)
*LOG(MD)*LOG(LOS)+C(421)*LOG(RN)*LOG(IPD)+C(423)*LOG(RN)
*LOG(LOS)+C(431)*LOG(MED)*LOG(IPD)+C(433)*LOG(MED)
*LOG(LOS)+C(441)*LOG(NMED)*LOG(IPD)+C(443)*LOG(NMED)
*LOG(LOS)+(0-C(411)-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)
+(0-C(413)-C(423)-C(433)-C(443))*LOG(MAT)*LOG(LOS)+C(51)
*LOG(BED)+0.5*C(511)*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)
+C(621)*LOG(RN)*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)
*LOG(NMED)*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)
*LOG(BED)+C(711)*LOG(BED)*LOG(IPD)+C(713)*LOG(BED)
*LOG(LOS)+C(83)*OPUC+C(91)*LOC1+C(92)*LOC2+C(93)*LOC3
+C(94)*LEV

Observations: 704

R-squared	0.967262	Mean dependent var	18.14215
Adjusted R-squared	0.965234	S.D. dependent var	0.962925
S.E. of regression	0.179544	Sum squared resid	21.34015
Durbin-Watson stat	1.307807		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(413)*LOG(LOS)

Observations: 704

R-squared	0.162078	Mean dependent var	0.032518
Adjusted R-squared	0.153650	S.D. dependent var	0.015180
S.E. of regression	0.013965	Sum squared resid	0.135741
Durbin-Watson stat	1.668370		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(423)*LOG(LOS)

Observations: 704

R-squared	0.203325	Mean dependent var	0.315047
Adjusted R-squared	0.195313	S.D. dependent var	0.066967
S.E. of regression	0.060072	Sum squared resid	2.511652
Durbin-Watson stat	1.273103		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(443)*LOG(LOS)

Observations: 704

R-squared	0.213527	Mean dependent var	0.030270
Adjusted R-squared	0.205617	S.D. dependent var	0.013749
S.E. of regression	0.012254	Sum squared resid	0.104515
Durbin-Watson stat	1.688116		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))

*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(413)-C(423)-C(433)-C(443))*LOG(LOS)

Observations: 704

R-squared	0.344136	Mean dependent var	0.507872
Adjusted R-squared	0.319952	S.D. dependent var	0.098438
S.E. of regression	0.081177	Sum squared resid	4.467782
Durbin-Watson stat	1.288636		

Omission of second and first-order variables

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 6 weight matrices, 7 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	4.587425	0.928114	4.942739	0.0000
C(21)	1.274758	0.301757	4.224447	0.0000
C(23)	1.080663	0.584115	1.850087	0.0644
C(211)	-0.079798	0.056801	-1.404878	0.1601
C(233)	-0.394609	0.175295	-2.251112	0.0244
C(213)	-0.192577	0.099832	-1.929010	0.0538
C(31)	-0.026318	0.010169	-2.588099	0.0097
C(32)	0.256786	0.038127	6.735102	0.0000
C(33)	0.122787	0.018725	6.557380	0.0000
C(34)	0.047887	0.008865	5.401625	0.0000
C(311)	0.013058	0.002224	5.870423	0.0000
C(322)	0.152569	0.011448	13.32734	0.0000
C(333)	0.090234	0.007973	11.31697	0.0000
C(344)	0.011458	0.002644	4.333287	0.0000
C(312)	-0.012161	0.003743	-3.249387	0.0012
C(313)	0.003648	0.002937	1.242211	0.2142
C(314)	0.004913	0.001627	3.019698	0.0025
C(323)	-0.060893	0.008279	-7.355334	0.0000
C(324)	-0.008556	0.003995	-2.141914	0.0323
C(334)	-0.000289	0.003264	-0.088460	0.9295
C(411)	-0.001200	0.001381	-0.868640	0.3851
C(413)	0.007046	0.002762	2.551507	0.0108
C(421)	-0.052724	0.005170	-10.19720	0.0000
C(423)	0.015105	0.010340	1.460798	0.1442
C(431)	-0.014216	0.002536	-5.606287	0.0000
C(433)	-0.002971	0.005070	-0.586065	0.5579
C(441)	-0.007923	0.001191	-6.651903	0.0000
C(443)	0.004677	0.002381	1.964510	0.0496
C(51)	-1.077193	0.273597	-3.937156	0.0001
C(511)	-0.004222	0.074218	-0.056891	0.9546
C(611)	0.006287	0.001499	4.194599	0.0000
C(621)	0.050887	0.005615	9.063391	0.0000
C(631)	-0.000266	0.002755	-0.096431	0.9232
C(641)	0.003645	0.001297	2.810393	0.0050
C(711)	0.087413	0.055917	1.563253	0.1181
C(713)	0.268704	0.106531	2.522299	0.0117
C(83)	-0.005507	0.000800	-6.887358	0.0000
C(91)	-0.003115	0.024754	-0.125841	0.8999
C(92)	0.046541	0.024111	1.930235	0.0537

C(93)	-0.009349	0.024169	-0.386800	0.6989
C(94)	0.005962	0.054442	0.109512	0.9128

Determinant residual covariance 1.40E-15

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(23)*LOG(LOS)+0.5*C(211)
*LOG(IPD)^2+0.5*C(233)*LOG(LOS)^2+C(213)*LOG(IPD)*LOG(LOS)
+C(31)*LOG(MD)+C(32)*LOG(RN)+C(33)*LOG(MED)+C(34)
*LOG(NMED)+(1-C(31)-C(32)-C(33)-C(34))*LOG(MAT)+0.5*C(311)
*LOG(MD)^2+0.5*C(322)*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5
*C(344)*LOG(NMED)^2+0.5*(0+C(311)+C(312)+C(313)+C(314)
+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)+C(334)
+C(314)+C(324)+C(334)+C(344))*LOG(MAT)^2+C(312)*LOG(MD)
*LOG(RN)+C(313)*LOG(MD)*LOG(MED)+C(314)*LOG(MD)
*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))*LOG(MD)*LOG(MAT)
+C(323)*LOG(RN)*LOG(MED)+C(324)*LOG(RN)*LOG(NMED)+(0
-C(312)-C(322)-C(323)-C(324))*LOG(RN)*LOG(MAT)+C(334)
*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)-C(334))
*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))*LOG(NMED)
*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(413)*LOG(MD)*LOG(LOS)
+C(421)*LOG(RN)*LOG(IPD)+C(423)*LOG(RN)*LOG(LOS)+C(431)
*LOG(MED)*LOG(IPD)+C(433)*LOG(MED)*LOG(LOS)+C(441)
*LOG(NMED)*LOG(IPD)+C(443)*LOG(NMED)*LOG(LOS)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(413)-C(423)
-C(433)-C(443))*LOG(MAT)*LOG(LOS)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(713)*LOG(BED)*LOG(LOS)+C(83)
*OPUC+C(91)*LOC1+C(92)*LOC2+C(93)*LOC3+C(94)*LEV

Observations: 704

R-squared	0.960128	Mean dependent var	18.14215
Adjusted R-squared	0.957722	S.D. dependent var	0.962925
S.E. of regression	0.197992	Sum squared resid	25.99022
Durbin-Watson stat	1.630475		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(413)*LOG(LOS)

Observations: 704

R-squared	0.179287	Mean dependent var	0.032518
Adjusted R-squared	0.171033	S.D. dependent var	0.015180
S.E. of regression	0.013821	Sum squared resid	0.132953
Durbin-Watson stat	1.647304		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(423)*LOG(LOS)

Observations: 704

R-squared	0.400147	Mean dependent var	0.315047
Adjusted R-squared	0.394114	S.D. dependent var	0.066967
S.E. of regression	0.052126	Sum squared resid	1.891137
Durbin-Watson stat	1.214124		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(443)*LOG(LOS)

Observations: 704

R-squared	0.256311	Mean dependent var	0.030270
Adjusted R-squared	0.248831	S.D. dependent var	0.013749

S.E. of regression	0.011916	Sum squared resid	0.098830
Durbin-Watson stat	1.678970		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(413)-C(423)-C(433)-C(443))*LOG(LOS)

Observations: 704

R-squared	0.549967	Mean dependent var	0.507872
Adjusted R-squared	0.533373	S.D. dependent var	0.098438
S.E. of regression	0.067243	Sum squared resid	3.065646
Durbin-Watson stat	1.172574		

Appendix F: Testing for the omission of average length of stay (LOS) variable

Omission of second-order variables

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 14 weight matrices, 15 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.350877	0.516224	4.553991	0.0000
C(21)	0.276011	0.090350	3.054899	0.0023
C(22)	0.170429	0.129937	1.311628	0.1897
C(23)	0.006985	0.006924	1.008866	0.3131
C(211)	0.032716	0.015471	2.114671	0.0345
C(222)	0.153632	0.019157	8.019524	0.0000
C(212)	-0.046606	0.014609	-3.190244	0.0014
C(31)	0.011473	0.013438	0.853764	0.3933
C(32)	0.378669	0.044240	8.559349	0.0000
C(33)	0.194853	0.023588	8.260544	0.0000
C(34)	0.086012	0.011674	7.367973	0.0000
C(311)	0.013876	0.002224	6.240369	0.0000
C(322)	0.199985	0.011388	17.56046	0.0000
C(333)	0.097084	0.007882	12.31750	0.0000
C(344)	0.012097	0.002654	4.557944	0.0000
C(312)	-0.009577	0.003765	-2.543257	0.0110
C(313)	0.003831	0.002908	1.317342	0.1878
C(314)	0.005563	0.001627	3.419541	0.0006
C(323)	-0.044906	0.008258	-5.437938	0.0000
C(324)	-0.005414	0.004035	-1.341931	0.1797
C(334)	0.001078	0.003252	0.331522	0.7403
C(411)	0.003256	0.001627	2.002052	0.0454
C(412)	-0.009014	0.001802	-5.001969	0.0000
C(421)	-0.005520	0.005371	-1.027665	0.3042
C(422)	-0.081902	0.005899	-13.88406	0.0000
C(431)	0.005195	0.002853	1.821143	0.0687
C(432)	-0.033890	0.003161	-10.72037	0.0000
C(441)	-0.002079	0.001395	-1.490725	0.1361
C(442)	-0.010785	0.001552	-6.948372	0.0000
C(51)	0.388908	0.086628	4.489391	0.0000
C(511)	0.071875	0.012198	5.892207	0.0000
C(611)	0.010898	0.001385	7.869169	0.0000
C(621)	0.089756	0.004584	19.57932	0.0000
C(631)	0.012330	0.002428	5.077394	0.0000
C(641)	0.008124	0.001195	6.798593	0.0000
C(711)	0.009507	0.010128	0.938682	0.3480
C(712)	-0.085035	0.011205	-7.588835	0.0000
C(83)	0.000696	0.000143	4.865572	0.0000
C(91)	-0.013371	0.004155	-3.218442	0.0013
C(92)	-0.011224	0.004026	-2.787906	0.0053
C(93)	-0.007813	0.004050	-1.928826	0.0538
C(94)	-0.039199	0.009540	-4.109008	0.0000

Determinant residual covariance	3.90E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+C(23)
*LOG(LOS)+0.5*C(211)*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+C(212)

*LOG(IPD)*LOG(OPD)+C(31)*LOG(MD)+C(32)*LOG(RN)+C(33)
*LOG(MED)+C(34)*LOG(NMED)+(1-C(31)-C(32)-C(33)-C(34))
*LOG(MAT)+0.5*C(311)*LOG(MD)^2+0.5*C(322)*LOG(RN)^2+0.5
*C(333)*LOG(MED)^2+0.5*C(344)*LOG(NMED)^2+0.5*(0+C(311)
+C(312)+C(313)+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)
+C(323)+C(333)+C(334)+C(314)+C(324)+C(334)+C(344))
*LOG(MAT)^2+C(312)*LOG(MD)*LOG(RN)+C(313)*LOG(MD)
*LOG(MED)+C(314)*LOG(MD)*LOG(NMED)+(0-C(311)-C(312)-C(313)
-C(314))*LOG(MD)*LOG(MAT)+C(323)*LOG(RN)*LOG(MED)+C(324)
*LOG(RN)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))*LOG(RN)
*LOG(MAT)+C(334)*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)
-C(334))*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(NMED)*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)
*LOG(MD)*LOG(OPD)+C(421)*LOG(RN)*LOG(IPD)+C(422)*LOG(RN)
*LOG(OPD)+C(431)*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)
*LOG(OPD)+C(441)*LOG(NMED)*LOG(IPD)+C(442)*LOG(NMED)
*LOG(OPD)+(0-C(411)-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)
+(0-C(412)-C(422)-C(432)-C(442))*LOG(MAT)*LOG(OPD)+C(51)
*LOG(BED)+0.5*C(511)*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)
+C(621)*LOG(RN)*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)
*LOG(NMED)*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)
*LOG(BED)+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)
*LOG(OPD)+C(83)*OPUC+C(91)*LOC1+C(92)*LOC2+C(93)*LOC3
+C(94)*LEV

Observations: 704

R-squared	0.977419	Mean dependent var	18.14215
Adjusted R-squared	0.976020	S.D. dependent var	0.962925
S.E. of regression	0.149113	Sum squared resid	14.71937
Durbin-Watson stat	1.399983		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)

Observations: 704

R-squared	0.194324	Mean dependent var	0.032518
Adjusted R-squared	0.186221	S.D. dependent var	0.015180
S.E. of regression	0.013694	Sum squared resid	0.130517
Durbin-Watson stat	1.699791		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)

Observations: 704

R-squared	0.379892	Mean dependent var	0.315047
Adjusted R-squared	0.373655	S.D. dependent var	0.066967
S.E. of regression	0.052999	Sum squared resid	1.954996
Durbin-Watson stat	1.324658		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)

Observations: 704

R-squared	0.282588	Mean dependent var	0.030270
Adjusted R-squared	0.275373	S.D. dependent var	0.013749
S.E. of regression	0.011704	Sum squared resid	0.095338
Durbin-Watson stat	1.684243		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))

*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)

Observations: 704

R-squared	0.560192	Mean dependent var	0.507872
Adjusted R-squared	0.543975	S.D. dependent var	0.098438
S.E. of regression	0.066475	Sum squared resid	2.995994
Durbin-Watson stat	1.373385		

Omission of second and first-order variables

Estimation Method: Iterative Seemingly Unrelated Regression
Sample: 1 704
Included observations: 704
Total system (balanced) observations 3520
Simultaneous weighting matrix & coefficient iteration
Convergence achieved after: 14 weight matrices, 15 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	2.300572	0.514949	4.467576	0.0000
C(21)	0.279344	0.090300	3.093508	0.0020
C(22)	0.179227	0.129836	1.380413	0.1675
C(211)	0.033216	0.015467	2.147552	0.0318
C(222)	0.152914	0.019160	7.980706	0.0000
C(212)	-0.046958	0.014608	-3.214489	0.0013
C(31)	0.011497	0.013437	0.855626	0.3923
C(32)	0.378631	0.044241	8.558313	0.0000
C(33)	0.194815	0.023593	8.257352	0.0000
C(34)	0.085970	0.011674	7.364314	0.0000
C(311)	0.013881	0.002224	6.241161	0.0000
C(322)	0.199964	0.011389	17.55783	0.0000
C(333)	0.097157	0.007884	12.32402	0.0000
C(344)	0.012105	0.002654	4.561745	0.0000
C(312)	-0.009550	0.003766	-2.535735	0.0113
C(313)	0.003818	0.002909	1.312491	0.1894
C(314)	0.005557	0.001627	3.416169	0.0006
C(323)	-0.044929	0.008258	-5.440491	0.0000
C(324)	-0.005411	0.004034	-1.341213	0.1799
C(334)	0.001101	0.003252	0.338710	0.7348
C(411)	0.003246	0.001627	1.995656	0.0460
C(412)	-0.009017	0.001802	-5.003496	0.0000
C(421)	-0.005750	0.005367	-1.071368	0.2841
C(422)	-0.081761	0.005898	-13.86235	0.0000
C(431)	0.005143	0.002853	1.802864	0.0715
C(432)	-0.033891	0.003162	-10.71824	0.0000
C(441)	-0.002087	0.001395	-1.496316	0.1347
C(442)	-0.010792	0.001552	-6.952525	0.0000
C(51)	0.385409	0.086598	4.450542	0.0000
C(511)	0.073148	0.012121	6.034830	0.0000
C(611)	0.010910	0.001385	7.877778	0.0000
C(621)	0.089864	0.004583	19.60985	0.0000
C(631)	0.012394	0.002428	5.104555	0.0000
C(641)	0.008145	0.001195	6.815812	0.0000
C(711)	0.008581	0.010087	0.850650	0.3950
C(712)	-0.084399	0.011195	-7.539200	0.0000
C(83)	0.000690	0.000143	4.825633	0.0000
C(91)	-0.013892	0.004130	-3.363946	0.0008
C(92)	-0.011098	0.004024	-2.758256	0.0058

C(93)	-0.008396	0.004008	-2.094720	0.0363
C(94)	-0.039045	0.009536	-4.094452	0.0000

Determinant residual covariance 3.90E-17

Equation: LOG(VC)=C(10)+C(21)*LOG(IPD)+C(22)*LOG(OPD)+0.5*C(211)
*LOG(IPD)^2+0.5*C(222)*LOG(OPD)^2+C(212)*LOG(IPD)*LOG(OPD)
+C(31)*LOG(MD)+C(32)*LOG(RN)+C(33)*LOG(MED)+C(34)
*LOG(NMED)+(1-C(31)-C(32)-C(33)-C(34))*LOG(MAT)+0.5*C(311)
*LOG(MD)^2+0.5*C(322)*LOG(RN)^2+0.5*C(333)*LOG(MED)^2+0.5
*C(344)*LOG(NMED)^2+0.5*(0+C(311)+C(312)+C(313)+C(314)
+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)+C(334)
+C(314)+C(324)+C(334)+C(344))*LOG(MAT)^2+C(312)*LOG(MD)
*LOG(RN)+C(313)*LOG(MD)*LOG(MED)+C(314)*LOG(MD)
*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))*LOG(MD)*LOG(MAT)
+C(323)*LOG(RN)*LOG(MED)+C(324)*LOG(RN)*LOG(NMED)+(0
-C(312)-C(322)-C(323)-C(324))*LOG(RN)*LOG(MAT)+C(334)
*LOG(MED)*LOG(NMED)+(0-C(313)-C(323)-C(333)-C(334))
*LOG(MED)*LOG(MAT)+(0-C(314)-C(324)-C(334)-C(344))*LOG(NMED)
*LOG(MAT)+C(411)*LOG(MD)*LOG(IPD)+C(412)*LOG(MD)*LOG(OPD)
+C(421)*LOG(RN)*LOG(IPD)+C(422)*LOG(RN)*LOG(OPD)+C(431)
*LOG(MED)*LOG(IPD)+C(432)*LOG(MED)*LOG(OPD)+C(441)
*LOG(NMED)*LOG(IPD)+C(442)*LOG(NMED)*LOG(OPD)+(0-C(411)
-C(421)-C(431)-C(441))*LOG(MAT)*LOG(IPD)+(0-C(412)-C(422)
-C(432)-C(442))*LOG(MAT)*LOG(OPD)+C(51)*LOG(BED)+0.5*C(511)
*LOG(BED)^2+C(611)*LOG(MD)*LOG(BED)+C(621)*LOG(RN)
*LOG(BED)+C(631)*LOG(MED)*LOG(BED)+C(641)*LOG(NMED)
*LOG(BED)+(0-C(611)-C(621)-C(631)-C(641))*LOG(MAT)*LOG(BED)
+C(711)*LOG(BED)*LOG(IPD)+C(712)*LOG(BED)*LOG(OPD)+C(83)
*OPUC+C(91)*LOC1+C(92)*LOC2+C(93)*LOC3+C(94)*LEV
Observations: 704

R-squared	0.977360	Mean dependent var	18.14215
Adjusted R-squared	0.975994	S.D. dependent var	0.962925
S.E. of regression	0.149193	Sum squared resid	14.75743
Durbin-Watson stat	1.401084		

Equation: SMD=C(31)+C(311)*LOG(MD)+C(312)*LOG(RN)+C(313)
*LOG(MED)+C(314)*LOG(NMED)+(0-C(311)-C(312)-C(313)-C(314))
*LOG(MAT)+C(611)*LOG(BED)+C(411)*LOG(IPD)+C(412)*LOG(OPD)
Observations: 704

R-squared	0.194278	Mean dependent var	0.032518
Adjusted R-squared	0.186174	S.D. dependent var	0.015180
S.E. of regression	0.013694	Sum squared resid	0.130525
Durbin-Watson stat	1.699721		

Equation: SRN=C(32)+C(322)*LOG(RN)+C(312)*LOG(MD)+C(323)
*LOG(MED)+C(324)*LOG(NMED)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(MAT)+C(621)*LOG(BED)+C(421)*LOG(IPD)+C(422)*LOG(OPD)
Observations: 704

R-squared	0.379915	Mean dependent var	0.315047
Adjusted R-squared	0.373679	S.D. dependent var	0.066967
S.E. of regression	0.052998	Sum squared resid	1.954922
Durbin-Watson stat	1.325080		

Equation: SNMED=C(34)+C(344)*LOG(NMED)+C(314)*LOG(MD)+C(324)
*LOG(RN)+C(334)*LOG(MED)+(0-C(314)-C(324)-C(334)-C(344))
*LOG(MAT)+C(641)*LOG(BED)+C(441)*LOG(IPD)+C(442)*LOG(OPD)
Observations: 704

R-squared	0.282416	Mean dependent var	0.030270
Adjusted R-squared	0.275199	S.D. dependent var	0.013749

S.E. of regression	0.011705	Sum squared resid	0.095361
Durbin-Watson stat	1.684144		

Equation: SMAT=(1-C(31)-C(32)-C(33)-C(34))+(0+C(311)+C(312)+C(313)
+C(314)+C(312)+C(322)+C(323)+C(324)+C(313)+C(323)+C(333)
+C(334)+C(314)+C(324)+C(334)+C(344))*LOG(MAT)+(0-C(311)
-C(312)-C(313)-C(314))*LOG(MD)+(0-C(312)-C(322)-C(323)-C(324))
*LOG(RN)+(0-C(313)-C(323)-C(333)-C(334))*LOG(MED)+(0-C(314)
-C(324)-C(334)-C(344))*LOG(NMED)+(0-C(611)-C(621)-C(631)
-C(641))*LOG(BED)+(0-C(411)-C(421)-C(431)-C(441))*LOG(IPD)+(0
-C(412)-C(422)-C(432)-C(442))*LOG(OPD)

Observations: 704

R-squared	0.559955	Mean dependent var	0.507872
Adjusted R-squared	0.543729	S.D. dependent var	0.098438
S.E. of regression	0.066493	Sum squared resid	2.997610
Durbin-Watson stat	1.373806		

Appendix G: Testing for heteroskedasticity of unit cost estimation models

1) Patient service cost proportion (initial specification)

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.462332	Prob. F(7,10)	0.8409
Obs*R-squared	4.401056	Prob. Chi-Square(7)	0.7326
Scaled explained SS	1.429933	Prob. Chi-Square(7)	0.9846

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1 18
Included observations: 18

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000977	0.001667	0.585999	0.5709
BED	3.50E-07	3.35E-06	0.104729	0.9187
OCP	-0.000127	0.001101	-0.115094	0.9106
LOS	-0.000220	0.000369	-0.595492	0.5647
LEV1	-0.000596	0.001020	-0.583879	0.5722
LEV2	0.000227	0.001724	0.131947	0.8976
SIM	-8.56E-06	0.001030	-0.008305	0.9935
CC	0.000649	0.000889	0.730851	0.4816

R-squared	0.244503	Mean dependent var	0.000486
Adjusted R-squared	-0.284345	S.D. dependent var	0.000725
S.E. of regression	0.000822	Akaike info criterion	-11.06973
Sum squared resid	6.75E-06	Schwarz criterion	-10.67401
Log likelihood	107.6276	Hannan-Quinn criter.	-11.01517
F-statistic	0.462332	Durbin-Watson stat	1.808519
Prob(F-statistic)	0.840934		

H_0: $VAR(\varepsilon_i) = \sigma^2$

H_1: $VAR(\varepsilon_i) = \sigma_i^2$

The test statistic is calculated as follows:

Degrees of freedom = number of slope coefficients in Breusch-Pagan-Godfrey test equation = 7.

χ^2-statistic = $NR^2 \sim \chi^2_7 = 4.401056$

Whilst the critical χ^2-value is $\chi^2_7 = 14.07$ at 5% level of significance,

$4.401056 < 14.07$

Hence we do not reject H_0, and so there is no evidence of heteroskedasticity.

2) Unit cost ratio estimation (initial specification)

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.084464	Prob. F(7,15)	0.4198
Obs*R-squared	7.728599	Prob. Chi-Square(7)	0.3571
Scaled explained SS	3.746422	Prob. Chi-Square(7)	0.8085

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1 23
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.203176	0.175568	1.157247	0.2653
BED	0.000197	0.000423	0.465854	0.6480
OCP	0.081246	0.090901	0.893781	0.3856
LOS	-0.053513	0.047392	-1.129154	0.2766
LEV1	-0.101900	0.141506	-0.720113	0.4825
LEV2	0.023888	0.222417	0.107402	0.9159
SIM	-0.089836	0.087562	-1.025959	0.3212
CC	0.056578	0.069840	0.810117	0.4305

R-squared	0.336026	Mean dependent var	0.076119
Adjusted R-squared	0.026172	S.D. dependent var	0.117504
S.E. of regression	0.115956	Akaike info criterion	-1.203001
Sum squared resid	0.201688	Schwarz criterion	-0.808046
Log likelihood	21.83451	Hannan-Quinn criter.	-1.103671
F-statistic	1.084464	Durbin-Watson stat	2.003505
Prob(F-statistic)	0.419829		

H_0: $VAR(\varepsilon_i) = \sigma^2$

H_1: $VAR(\varepsilon_i) = \sigma_i^2$

The test statistic is calculated as follows:

Degrees of freedom = number of slope coefficients in Breusch-Pagan-Godfrey test equation = 7.

χ^2-statistic = $NR^2 \sim \chi^2_7 = 7.728599$

Whilst the critical χ^2-value is $\chi^2_7 = 14.07$ at 5% level of significance,

$7.728599 < 14.07$

Hence we do not reject H_0, and so there is no evidence of heteroskedasticity.

Appendix H: EViews' estimation for cost proportion of patient services (initial regression run)

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)
+C(5)*LEV1+C(6)*LEV2+C(7)*SIM+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.218497	0.067677	-3.228551	0.0090
C(2)	0.050433	0.020488	2.461544	0.0336
C(3)	0.048640	0.026644	1.825557	0.0979
C(4)	-0.056667	0.060326	-0.939343	0.3697
C(5)	0.022674	0.035737	0.634461	0.5400
C(6)	-0.005522	0.050000	-0.110429	0.9143
C(7)	-0.000253	0.040889	-0.006190	0.9952
C(8)	-0.020097	0.034630	-0.580321	0.5745

R-squared	0.815474	Mean dependent var	-0.106379
Adjusted R-squared	0.686306	S.D. dependent var	0.052782
S.E. of regression	0.029562	Akaike info criterion	-3.903544
Sum squared resid	0.008739	Schwarz criterion	-3.507823
Log likelihood	43.13190	Hannan-Quinn criter.	-3.848980
F-statistic	6.313274	Durbin-Watson stat	1.766322
Prob(F-statistic)	0.004968		

Parameters:
C(1): θ_0 = constant
C(2): θ_1 = BED
C(3): θ_2 = OCP
C(4): θ_3 = LOS
C(5): ψ_1 = LEV_1
C(6): ψ_2 = LEV_2
C(7): ψ_3 = SIM
C(8): ψ_4 = CC

Appendix I: Testing for different specifications for cost proportion of patient services

1) Omission of LEV1 and LEV2

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)
+C(7)*SIM+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.222754	0.056312	-3.955690	0.0019
C(2)	0.059107	0.011733	5.037841	0.0003
C(3)	0.046998	0.023550	1.995623	0.0692
C(4)	-0.075042	0.052208	-1.437373	0.1762
C(7)	-0.013989	0.034903	-0.400796	0.6956
C(8)	-0.024677	0.031824	-0.775430	0.4531

R-squared	0.803746	Mean dependent var	-0.106379
Adjusted R-squared	0.721974	S.D. dependent var	0.052782
S.E. of regression	0.027831	Akaike info criterion	-4.064147
Sum squared resid	0.009295	Schwarz criterion	-3.767357
Log likelihood	42.57733	Hannan-Quinn criter.	-4.023224
F-statistic	9.829057	Durbin-Watson stat	2.144295
Prob(F-statistic)	0.000636		

2) Omission of SIM

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)
+C(5)*LEV1+C(6)*LEV2+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.218675	0.058397	-3.744662	0.0032
C(2)	0.050377	0.017548	2.870777	0.0152
C(3)	0.048643	0.025401	1.914995	0.0818
C(4)	-0.056497	0.051260	-1.102169	0.2939
C(5)	0.022745	0.032231	0.705695	0.4951
C(6)	-0.005545	0.047535	-0.116654	0.9092
C(8)	-0.019914	0.017372	-1.146319	0.2760

R-squared	0.815473	Mean dependent var	-0.106379
Adjusted R-squared	0.714822	S.D. dependent var	0.052782
S.E. of regression	0.028186	Akaike info criterion	-4.014651
Sum squared resid	0.008739	Schwarz criterion	-3.668396
Log likelihood	43.13186	Hannan-Quinn criter.	-3.966907
F-statistic	8.101997	Durbin-Watson stat	1.765152
Prob(F-statistic)	0.001597		

3) Omission of CC

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)
+C(5)*LEV1+C(6)*LEV2+C(7)*SIM

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.236560	0.058255	-4.060796	0.0019
C(2)	0.045577	0.018129	2.514027	0.0288
C(3)	0.046747	0.025634	1.823645	0.0955
C(4)	-0.042654	0.053590	-0.795931	0.4429
C(5)	0.027170	0.033818	0.803421	0.4387
C(6)	-0.002165	0.048144	-0.044963	0.9649
C(7)	0.019926	0.020855	0.955458	0.3599

R-squared	0.809260	Mean dependent var	-0.106379
Adjusted R-squared	0.705220	S.D. dependent var	0.052782
S.E. of regression	0.028657	Akaike info criterion	-3.981533
Sum squared resid	0.009033	Schwarz criterion	-3.635277
Log likelihood	42.83379	Hannan-Quinn criter.	-3.933789
F-statistic	7.778340	Durbin-Watson stat	1.730413
Prob(F-statistic)	0.001892		

4) Omission of SIM and CC

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)
+C(5)*LEV1+C(6)*LEV2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.232471	0.057886	-4.016021	0.0017
C(2)	0.048897	0.017728	2.758130	0.0173
C(3)	0.041128	0.024860	1.654425	0.1239
C(4)	-0.054679	0.051902	-1.053520	0.3129
C(5)	0.018363	0.032420	0.566420	0.5815
C(6)	0.013209	0.045211	0.292154	0.7752

R-squared	0.793430	Mean dependent var	-0.106379
Adjusted R-squared	0.707359	S.D. dependent var	0.052782
S.E. of regression	0.028553	Akaike info criterion	-4.012917
Sum squared resid	0.009783	Schwarz criterion	-3.716127
Log likelihood	42.11626	Hannan-Quinn criter.	-3.971994
F-statistic	9.218338	Durbin-Watson stat	1.893237
Prob(F-statistic)	0.000851		

5) Omission of LEV1, LEV2, SIM, and CC

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)*LOG(LOS)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.249169	0.042385	-5.878709	0.0000
C(2)	0.056328	0.010261	5.489601	0.0001
C(3)	0.043438	0.022388	1.940218	0.0728
C(4)	-0.062779	0.046735	-1.343296	0.2005

R-squared	0.787791	Mean dependent var	-0.106379
Adjusted R-squared	0.742318	S.D. dependent var	0.052782
S.E. of regression	0.026793	Akaike info criterion	-4.208207
Sum squared resid	0.010050	Schwarz criterion	-4.010347
Log likelihood	41.87387	Hannan-Quinn criter.	-4.180925
F-statistic	17.32424	Durbin-Watson stat	1.980123
Prob(F-statistic)	0.000055		

6) Omission of LOS, LEV1, LEV2, SIM, and CC

Dependent Variable: LOG(CPS/FC)
Method: Least Squares
Sample: 1 18
Included observations: 18
LOG(CPS/FC)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.291192	0.029355	-9.919800	0.0000
C(2)	0.045618	0.006629	6.881288	0.0000
C(3)	0.028072	0.019755	1.421037	0.1758

R-squared	0.760440	Mean dependent var	-0.106379
Adjusted R-squared	0.728498	S.D. dependent var	0.052782
S.E. of regression	0.027502	Akaike info criterion	-4.198085
Sum squared resid	0.011346	Schwarz criterion	-4.049689
Log likelihood	40.78276	Hannan-Quinn criter.	-4.177623
F-statistic	23.80736	Durbin-Watson stat	2.056579
Prob(F-statistic)	0.000022		

Appendix J: EViews' estimation for unit cost ratio estimation (initial regression run)

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)
*LOG(LOS)+C(5)*LEV1+C(6)*LEV2+C(7)*SIM+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.416984	0.738405	-3.273248	0.0051
C(2)	-0.005437	0.172327	-0.031550	0.9752
C(3)	0.183475	0.211302	0.868305	0.3989
C(4)	-0.166414	0.541431	-0.307360	0.7628
C(5)	-0.745051	0.360299	-2.067868	0.0564
C(6)	-0.652684	0.522384	-1.249433	0.2307
C(7)	0.195978	0.266098	0.736487	0.4728
C(8)	0.155543	0.213087	0.729953	0.4767

R-squared	0.615491	Mean dependent var	-2.751956
Adjusted R-squared	0.436053	S.D. dependent var	0.454930
S.E. of regression	0.341636	Akaike info criterion	0.958066
Sum squared resid	1.750727	Schwarz criterion	1.353020
Log likelihood	-3.017759	Hannan-Quinn criter.	1.057396
F-statistic	3.430111	Durbin-Watson stat	1.885510
Prob(F-statistic)	0.021424		

Parameters:
C(1): ς_0 = constant
C(2): ς_1 = BED
C(3): ς_2 = OCP
C(4): ς_3 = LOS
C(5): ρ_1 = LEV_1
C(6): ρ_2 = LEV_2
C(7): ρ_3 = SIM
C(8): ρ_4 = CC

Appendix K: Testing for different specifications of unit cost ratio estimation

1) Omission of BED

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(3)*LOG(OCP)+C(4)*LOG(LOS)+C(5)*LEV1
+C(6)*LEV2+C(7)*SIM+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.424695	0.674689	-3.593797	0.0024
C(3)	0.186155	0.187340	0.993673	0.3352
C(4)	-0.175027	0.452733	-0.386602	0.7041
C(5)	-0.754007	0.214846	-3.509524	0.0029
C(6)	-0.661083	0.435208	-1.519004	0.1483
C(7)	0.193661	0.247648	0.782000	0.4456
C(8)	0.154177	0.202019	0.763177	0.4565

R-squared	0.615465	Mean dependent var	-2.751956
Adjusted R-squared	0.471265	S.D. dependent var	0.454930
S.E. of regression	0.330799	Akaike info criterion	0.871176
Sum squared resid	1.750843	Schwarz criterion	1.216761
Log likelihood	-3.018522	Hannan-Quinn criter.	0.958090
F-statistic	4.268123	Durbin-Watson stat	1.888366
Prob(F-statistic)	0.009351		

2) Omission of LOS

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(5)*LEV1
+C(6)*LEV2+C(7)*SIM+C(8)*CC

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.555312	0.568596	-4.494071	0.0004
C(2)	-0.032144	0.144544	-0.222381	0.8268
C(3)	0.154555	0.183765	0.841046	0.4127
C(5)	-0.728936	0.346230	-2.105353	0.0514
C(6)	-0.677014	0.501528	-1.349902	0.1958
C(7)	0.229717	0.235442	0.975685	0.3437
C(8)	0.177649	0.194824	0.911844	0.3754

R-squared	0.613069	Mean dependent var	-2.751956
Adjusted R-squared	0.467970	S.D. dependent var	0.454930
S.E. of regression	0.331828	Akaike info criterion	0.877388
Sum squared resid	1.761753	Schwarz criterion	1.222973
Log likelihood	-3.089959	Hannan-Quinn criter.	0.964301
F-statistic	4.225178	Durbin-Watson stat	1.871903
Prob(F-statistic)	0.009765		

3) Omission of SIM and CC

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(4)
*LOG(LOS)+C(5)*LEV1+C(6)*LEV2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.168000	0.640902	-3.382733	0.0035
C(2)	0.030198	0.158808	0.190155	0.8514
C(3)	0.250069	0.185546	1.347748	0.1954
C(4)	-0.341391	0.471712	-0.723727	0.4791
C(5)	-0.793373	0.335213	-2.366772	0.0301
C(6)	-0.611978	0.488688	-1.252289	0.2274

R-squared	0.599334	Mean dependent var	-2.751956
Adjusted R-squared	0.481491	S.D. dependent var	0.454930
S.E. of regression	0.327584	Akaike info criterion	0.825314
Sum squared resid	1.824291	Schwarz criterion	1.121529
Log likelihood	-3.491106	Hannan-Quinn criter.	0.899811
F-statistic	5.085871	Durbin-Watson stat	1.891887
Prob(F-statistic)	0.004949		

4) Omission of LOS, SIM, and CC

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(2)*LOG(BED)+C(3)*LOG(OCP)+C(5)*LEV1
+C(6)*LEV2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.415060	0.535197	-4.512466	0.0003
C(2)	-0.021079	0.140234	-0.150311	0.8822
C(3)	0.205211	0.172558	1.189226	0.2498
C(5)	-0.776708	0.329968	-2.353889	0.0301
C(6)	-0.649174	0.479506	-1.353839	0.1925

R-squared	0.586989	Mean dependent var	-2.751956
Adjusted R-squared	0.495209	S.D. dependent var	0.454930
S.E. of regression	0.323222	Akaike info criterion	0.768703
Sum squared resid	1.880499	Schwarz criterion	1.015549
Log likelihood	-3.840080	Hannan-Quinn criter.	0.830784
F-statistic	6.395600	Durbin-Watson stat	1.844241
Prob(F-statistic)	0.002197		

5) Omission of BED, SIM, and CC

Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(3)*LOG(OCP)+C(4)*LOG(LOS)+C(5)*LEV1
+C(6)*LEV2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.106343	0.537823	-3.916423	0.0010
C(3)	0.238326	0.170218	1.400121	0.1785
C(4)	-0.301372	0.410706	-0.733791	0.4725
C(5)	-0.743616	0.203834	-3.648142	0.0018
C(6)	-0.557149	0.383850	-1.451476	0.1639

R-squared	0.598482	Mean dependent var	-2.751956
Adjusted R-squared	0.509256	S.D. dependent var	0.454930
S.E. of regression	0.318693	Akaike info criterion	0.740482
Sum squared resid	1.828172	Schwarz criterion	0.987328
Log likelihood	-3.515541	Hannan-Quinn criter.	0.802563
F-statistic	6.707462	Durbin-Watson stat	1.865235
Prob(F-statistic)	0.001732		

6) Omission of BED, LOS, SIM, and CC

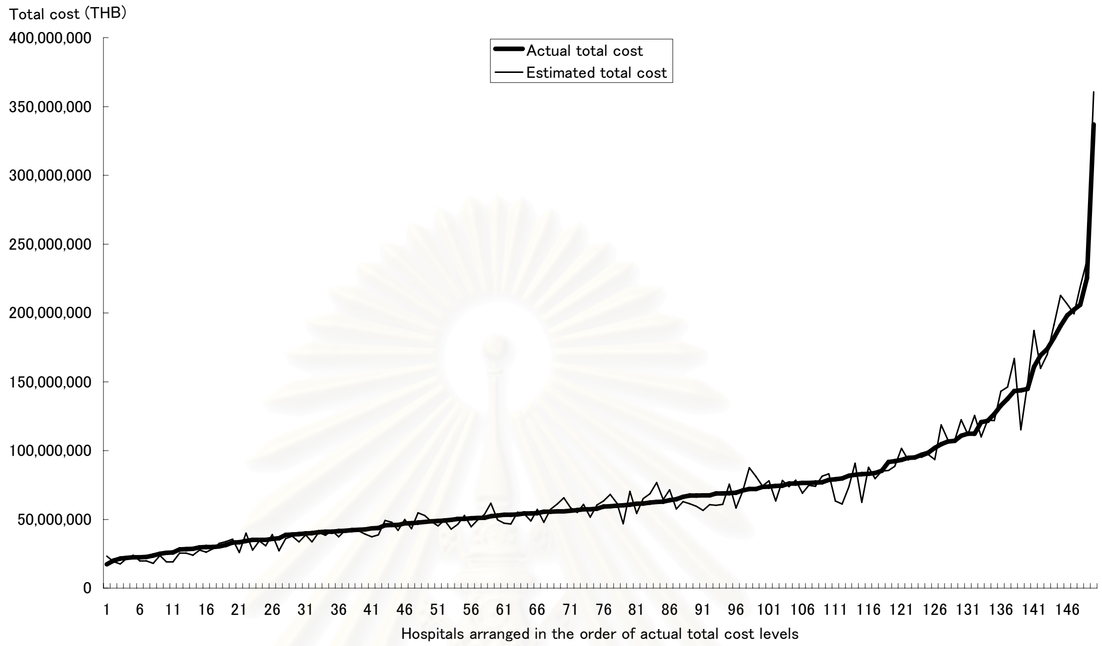
Dependent Variable: LOG(UCOP/UCIP)
Method: Least Squares
Sample: 1 23
Included observations: 23
LOG(UCOP/UCIP)=C(1)+C(3)*LOG(OCP)+C(5)*LEV1+C(6)*LEV2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.494032	0.099336	-25.10697	0.0000
C(3)	0.210862	0.164023	1.285563	0.2140
C(5)	-0.818367	0.174396	-4.692591	0.0002
C(6)	-0.700755	0.326177	-2.148387	0.0448

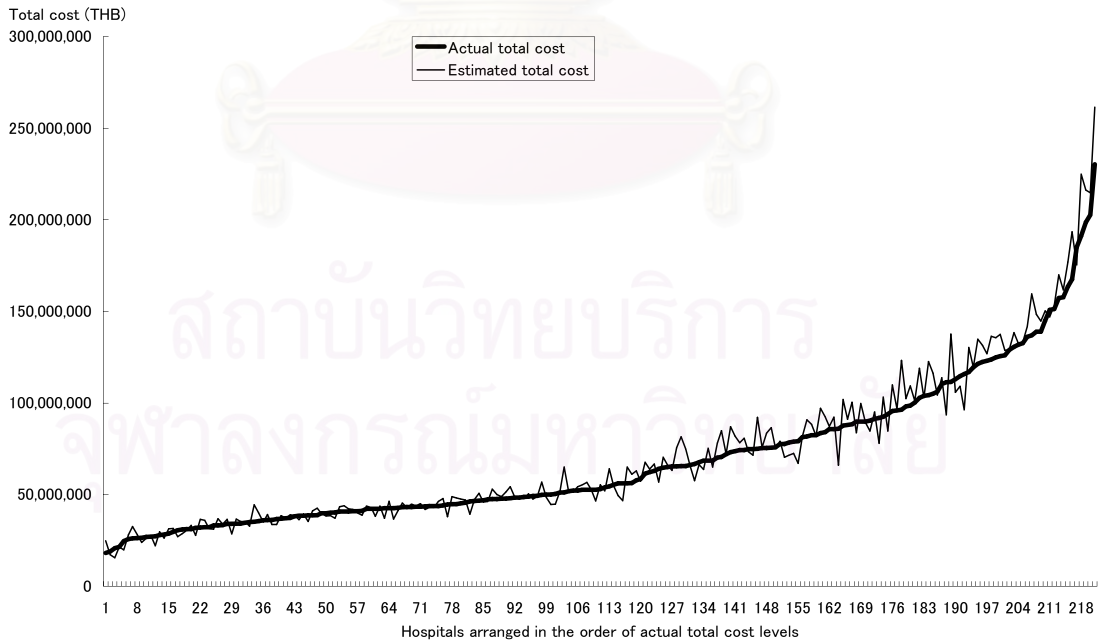
R-squared	0.586471	Mean dependent var	-2.751956
Adjusted R-squared	0.521177	S.D. dependent var	0.454930
S.E. of regression	0.314798	Akaike info criterion	0.683000
Sum squared resid	1.882859	Schwarz criterion	0.880478
Log likelihood	-3.854505	Hannan-Quinn criter.	0.732665
F-statistic	8.981990	Durbin-Watson stat	1.862495
Prob(F-statistic)	0.000650		

Appendix L: Actual vs. estimated total costs of individual hospitals

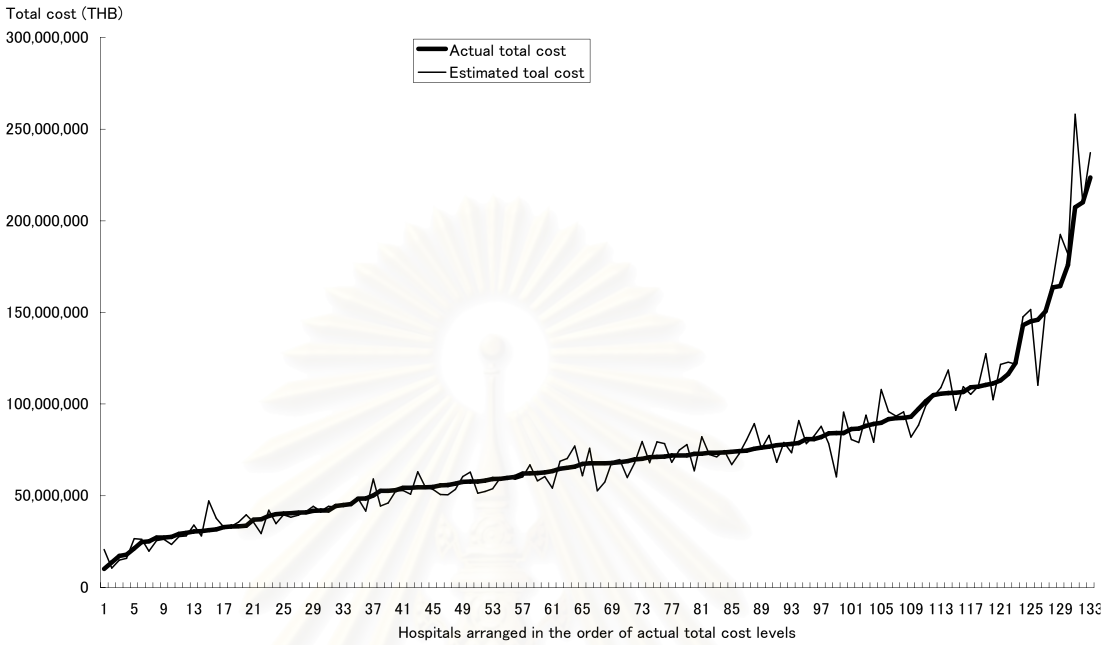
Community hospital (Central)



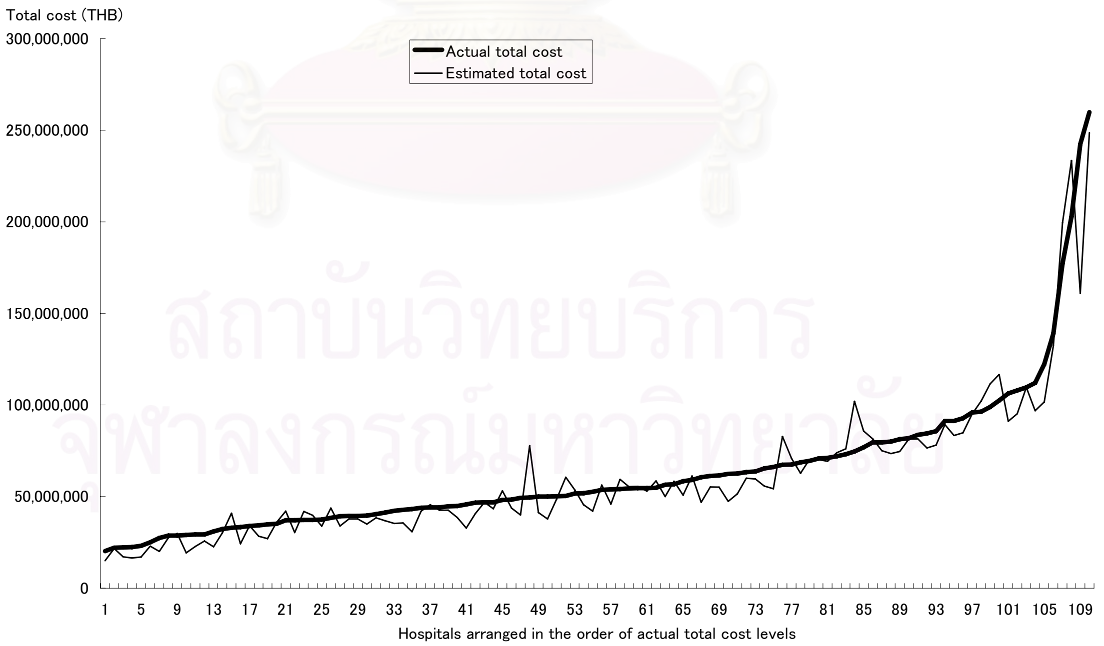
Community hospital (East)



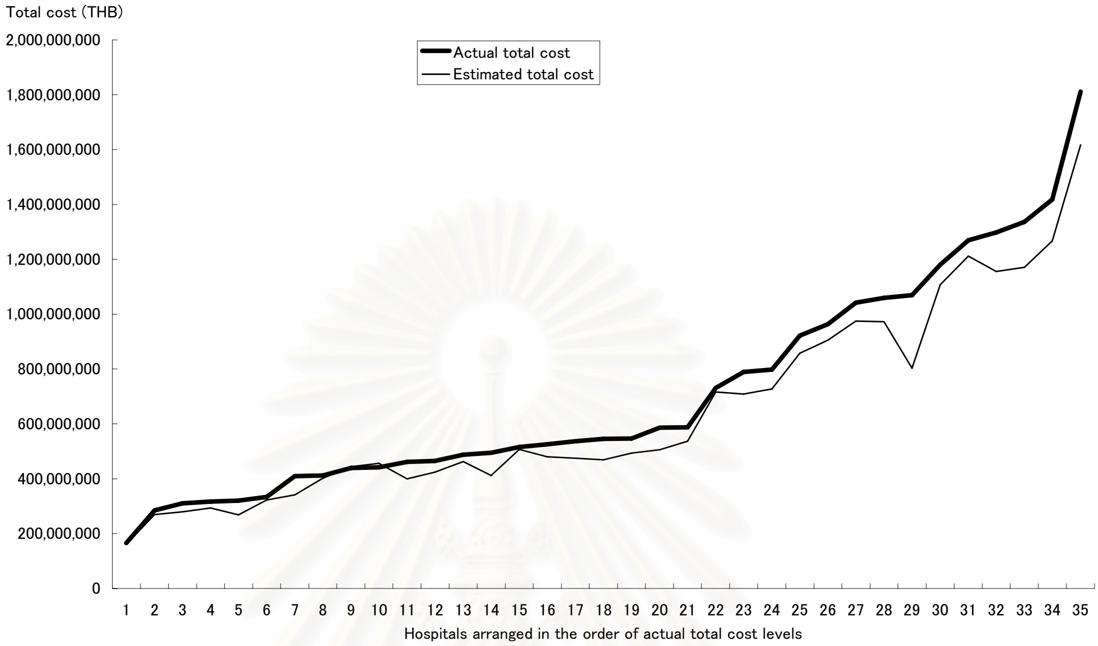
Community hospital (North)



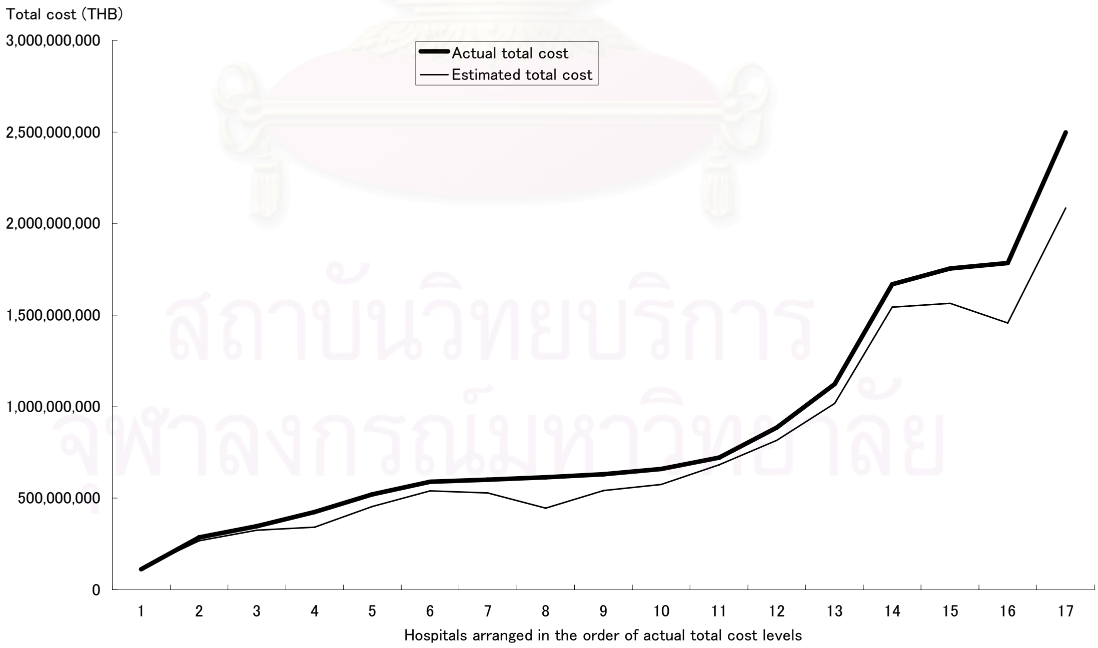
Community hospital (South)



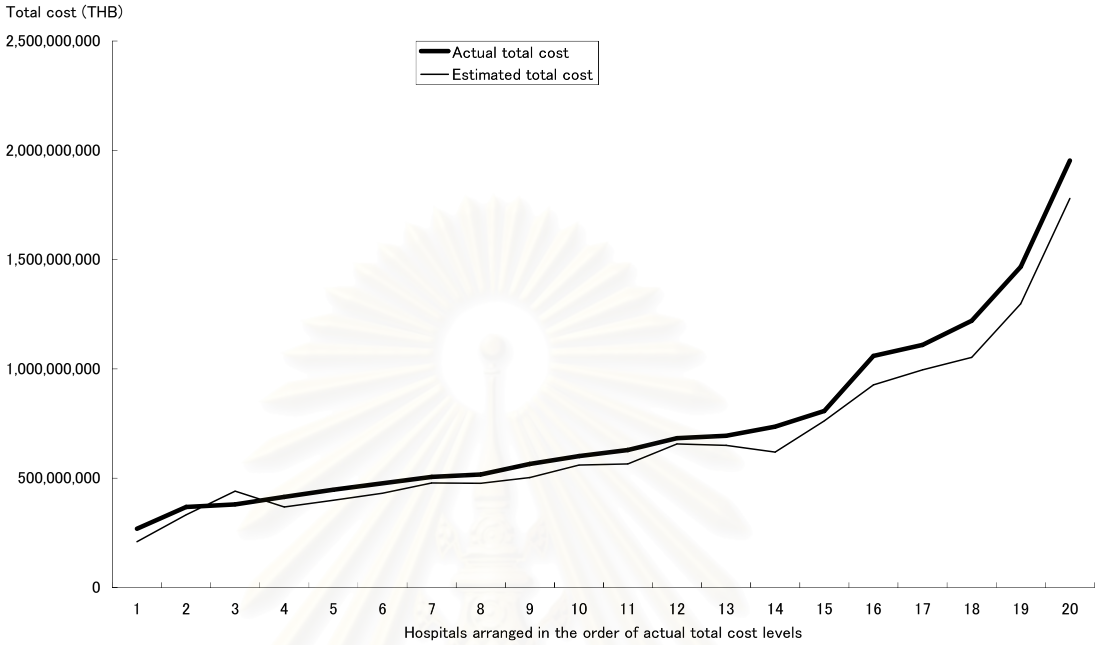
Provincial hospital (Central)



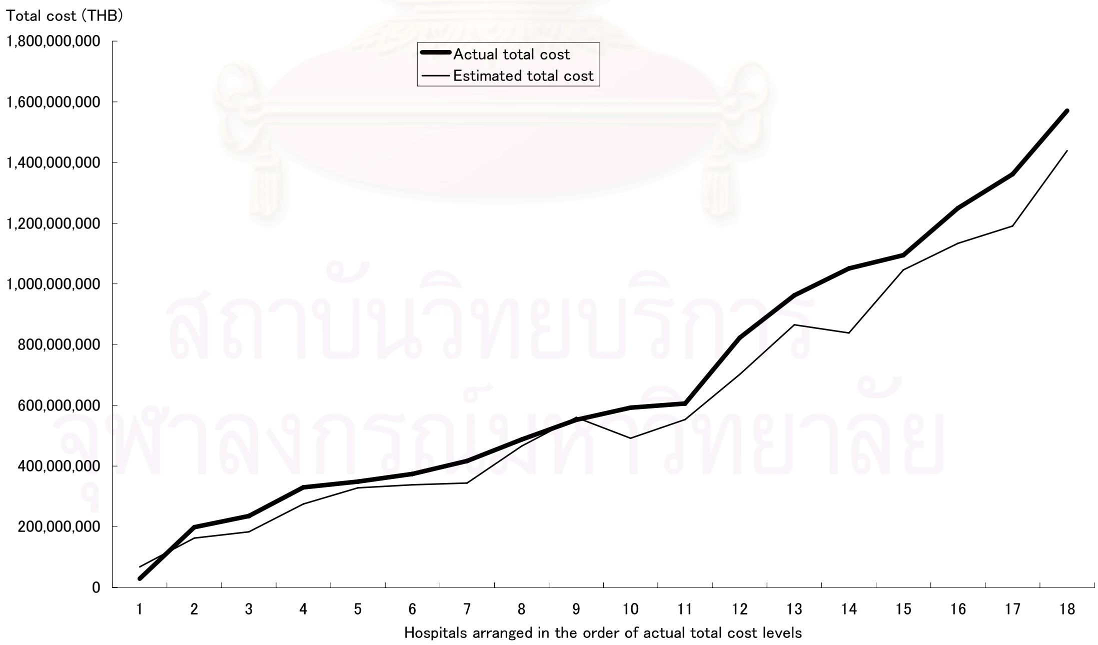
Provincial hospital (East)



Provincial hospital (North)

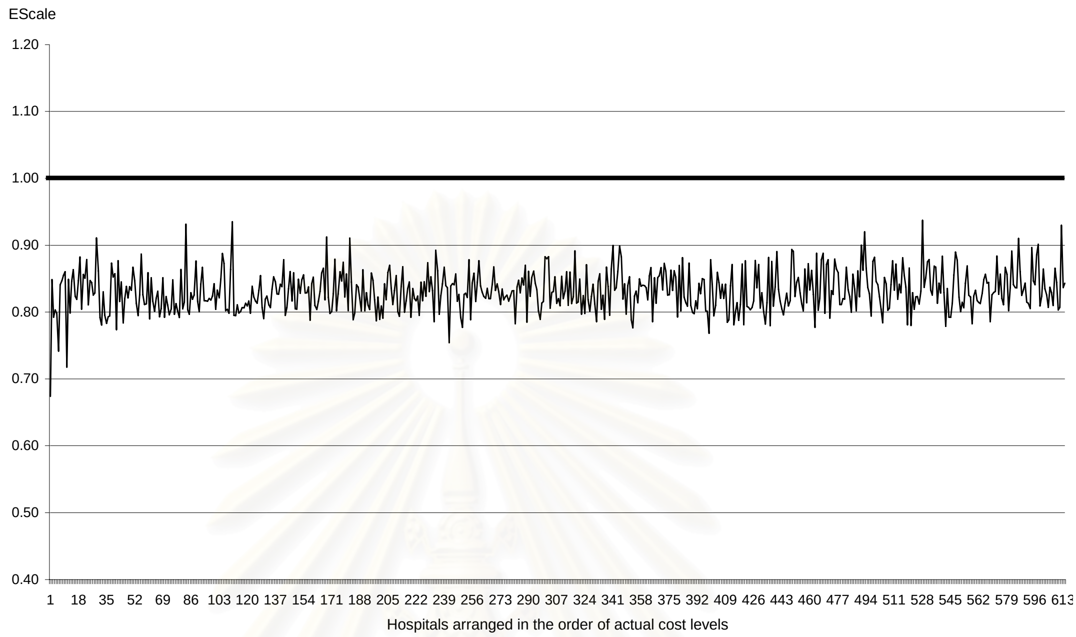


Provincial hospital (South)

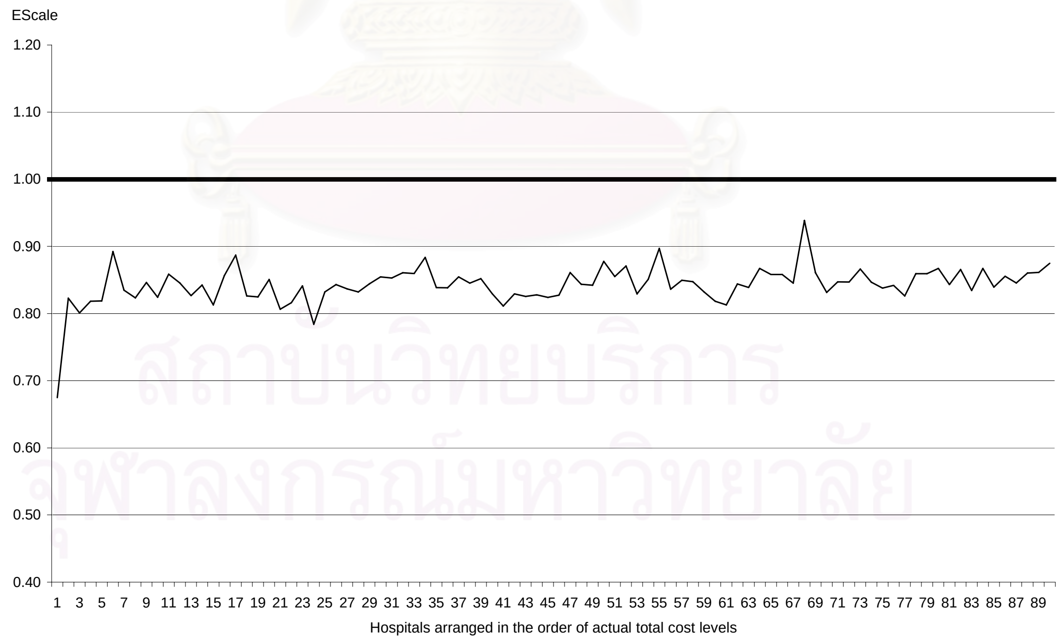


Appendix M: Economies of scales for individual hospitals

Community hospital



Provincial hospital



NB: Diseconomies of scale (EScale < 1) is observed in all sample hospitals.

Appendix N: Walt test results for weak cost complementarities (WCC)

H_0: $\beta_1\beta_2 + \beta_{12} = 0$

H_1: $\beta_1\beta_2 + \beta_{12} \neq 0$

Wald Test:

Test Statistic	Value	df	Probability
Chi-square	0.016751	1	0.8970

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(21)*C(22) + C(212)	-0.004662	0.036020

Delta method computed using analytic derivatives.

H_0: $\beta_2\beta_3 + \beta_{23} = 0$

H_0: $\beta_2\beta_3 + \beta_{23} \neq 0$

Wald Test:

Test Statistic	Value	df	Probability
Chi-square	5.533589	1	0.0187

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(22)*C(23) + C(223)	-0.041640	0.017702

Delta method computed using analytic derivatives.

BIOGRAPHY

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	2001–2004	*International Programme Director, Japan* *Chief of Operations, Afghanistan* Medical Relief Unit
	2001–2001	*Project Officer, Sierra Leone* Médecins Sans Frontières
	1999–1999	*Survey Officer, Cambodia/Mozambique* The HALO Trust
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