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รายงานวิจัยฉบับสมบูรณ์

โครงการ

การศึกษาประสิทธิภาพของการบริการสาธารณสุขไทย จากแบบจำลองทรานสลอก

โดย ผู้ช่วยศาสตราจารย์ ดร. ชุติมา สุรรัตน์เดชา

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คณะผู้วิจัย	สังกัด
1. ผู้ช่วยศาสตราจารย์ ดร. ชุติมา สุรรัตน์เดชา	มหาวิทยาลัยสุโขทัยธรรมาธิราช
2. Professor Albert A. Okunade, Ph.D.	The University of Memphis, USA

สนับสนุนโดยสำนักงานกองทุนสนับสนุนการวิจัย
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Abstract

Project Title: Is Production of Healthcare in Thailand Efficient?: Evidence from a Translog Model.

Investigators: Chutima SURARATDECHA[*] & Albert A. OKUNADE[**]

[*]School of Economics, Sukhothai Thammathirat Open University, Bangpood, Pakkred, Nonthaburi 11120, Thailand. [**]Department of Economics, The University of Memphis, Memphis, TN 38152, USA.

E-mail address: ecasschu@stou.ac.th

Project Period: 2 years

Objectives: 1. To analyze an efficiency of Thai health care system 2. To scrutinize the impact of health resources on health 3. To investigate the possibility of substitution among health manpower and 4. To measure the economies of scale.

Methodology: Data used in this study are secondary data collected from the Ministry of Public Health and the National Statistical Office. The data set is annually aggregated by regions (Central, North, Northeast, South and Bangkok metropolis) from year 1982 to 1997. The analysis was performed by SPSS and SAS statistical package.

Results: The results show that the marginal products for most of the factors except the physicians and pharmacists are positive. The Allen and Morishima elasticities of substitution give the same conclusion that all inputs can be substituted. Furthermore, the production of Thai health care is at the rate of significant scale economies and a negative rate of technical change implies that Thai health production is not the technology driven process.

Conclusions: The more flexible production function for Thai health care is confirmed. The results of marginal product, elasticity of substitution and technical change call for the need to redirect the aim of national health plan.

Suggestions: The future health policy should direct toward the goal to increase more contribution of each input to the health output and pay more attention to productive factors such as nurses and beds. Pharmacists should substitute for physicians according to the result from marginal product.

Keywords: Translog, elasticity of substitution, Thai health care

บทคัดย่อ

โครงการ การศึกษาประสิทธิภาพของการบริการสาธารณสุขไทยจากแบบจำลองทรานสลอก

คณะผู้วิจัย ผู้ช่วยศาสตราจารย์ ดร. ชุติมา สุรรัตน์เดชา
มหาวิทยาลัยสุโขทัยธรรมาธิราช
Professor Albert A. Okunade, Ph.D. The University of Memphis.

E-mail address ecasschu@stou.ac.th

ระยะเวลา 2 ปี

วัตถุประสงค์
1. เพื่อวิเคราะห์ประสิทธิภาพของระบบสาธารณสุขไทย
2. เพื่อศึกษาผลกระทบของทรัพยากรสาธารณสุขต่อสุขภาพ
3. เพื่อตรวจสอบความเป็นไปได้ของการทดแทนกันระหว่างบุคลากรทาง ' สาธารณสุข
4. เพื่อวัดการประหยัดเนื่องมาจากการขยายขนาด

ระเบียบวิธีวิจัย ข้อมูลที่ใช้ในดารศึกษาเป็นข้อมูลทุติยภูมิที่รวบรวมจากกระทรวงสาธารณสุขและสำนักงานสถิติแห่งชาติ ประกอบไปด้วยข้อมูลในระดับภาคได้แก่ ภาคกลาง ภาคเหนือ ภาคตะวันออกเฉียงเหนือ ภาคใต้ และกรุงเทพมหานคร มีระยะเวลาตั้งแต่ปี พ.ศ. 2525 ถึงปี พ.ศ. 2540 การวิเคราะห์ข้อมูลอาศัยโปรแกรมทางสถิติ SPSS และ SAS

ผลการวิจัย ผลผลิตส่วนเพิ่มสำหรับปัจจัยส่วนใหญ่มีค่าเป็นลบยกเว้นสำหรับบุคลากรแพทย์และเภสัชกร ความยืดหยุ่นของการทดแทนกันของอัลเลนและโมริชิมาให้ผลสรุปที่เมหือนกันกล่าวคือ ปัจจัยทุกชนิดสามารถทดแทนกันได้ นอกจากนี้ การที่การผลิตสุขภาพของไทยอยู่ในสภาพที่มีการประหยัดเนื่องมาจากการขยายขนาดและมีอัตราการเปลี่ยนแปลงทางเทคโนโลยีที่เป็นลบแสดงให้เห็นว่าการผลิตสุขภาพของไทยไม่ใช่ลักษณะที่ถูกกระตุ้นโดยเทคโนโลยี

สรุปสาระสำคัญ รูปแบบฟังก์ชันการผลิตสุขภาพของไทยที่มีความยืดหยุ่นมีความเหมาะสม ผลจากค่าผลิตผลส่วนเพิ่ม ความยืดหยุ่นของการทดแทนกัน และการเปลี่ยนแปลงทางเทคนิคแสดงถึงความจำเป็นที่จะเปลี่ยนแปลงเป้าหมายของการวางแผนทางสุขภาพของประเทศ

ข้อเสนอแนะ นโยบายสุขภาพในอนาคตควรจะมุ่งไปในทิศทางที่จะเพิ่มประสิทธิภาพของปัจจัยแต่ละชนิดและให้ความสนใจต่อปัจจัยการผลิตที่มีผลิตภาพสูงกว่าปัจจัยอื่น ๆ เช่น พยาบาลและเตียง ควรจะทดแทนแพทย์ด้วยเภสัชกรมากขึ้นตามผลที่ได้จากค่าผลิตผลส่วนเพิ่ม

คำสำคัญ ทรานสลอก ความยืดหยุ่นของการทดแทนกัน สาธารณสุขไทย

Executive Summary

Despite the growing importance of health care sector in competing for resources and intensively influencing the population health, no empirical studies has explicitly acknowledged the efficiency of health care in Thailand. The phenomenal growth in the levels of private and public expenditures on health in Thailand as compared with other private and public spendings, and in the factors of health production, however, raises the question of whether an efficiency is correctly defined and applied to the deployment of resources currently devoted to health. Consequently, the translog production function model was estimated for Thai healthcare system using 1982-1997 annual time-series data comprising five cross-sectional regions per year. An analysis of the health production function reveals the efficiency of Thai healthcare, marginal products and input factor substitution possibilities. The investigation shows that the marginal products for most of the health factors except the physicians and pharmacists are positive. The Allen and Morishima elasticities of substitution give the same conclusion that all inputs can be substituted. Furthermore, the production of Thai health care is at the rate of significant scale economies. And a negative rate of technical change, therefore, implies that Thai health production is not the technology driven process. The implications of our findings for policy are explored.

Is Production of Healthcare in Thailand Efficient?: Evidence from a Translog Model

I. Introduction

Thailand's health care system is a public/private mix in delivery and financing. Government not only provides subsidy to public facilities and some segments of population e.g., the poor, elderly, children, and disabled, but also simultaneously implements market-driven policies for the private sector health care. Over the years, public health system has been expanded and developed throughout the country in all provincial areas. Private sector medicine, on the other hand, is largely curative, growing speedily and concentrated in Bangkok metropolis and almost every municipality of the country.

The mark of expansion is depicted by Wibulpholprasert et al (1998). Their investigation showed the evidence of an increasing acquisition of high cost medical devices such as MRI and CT scanner at both public and private facilities. The private sector, however, showed a more significantly positive increasing trend during 1988 -1996 for MRI and 1980-1995 for CT scanner. The private bed share also increased from 11 percent in 1989 to 23 percent in 1995. The 1995 health resource survey, however, showed 42-60 percent private bed occupancy indicating the significant underutilization of capacity (Ministry of Public Health (MOPH), 1997).

As Thailand moves toward industrialization, more people ought to be able to access and receive medical services based on available medical technology due to their growing incomes. Personal income is important in health expenditure for Thais because approximately 70 percent of the nation' s health Baht is currently from private households. However, from 1996 provincial health survey (MOPH), about 65 percent of population possess some types of health care security. These health securities are varied and include government/state enterprise health security scheme. The existing health securities comprise of the social security fund, workmen's compensation fund, private contracted by employers health insurance, private insurance, public volunteer health insurance card (health card project), low income welfare card, as well as free care for school children, children (0-12 years), the elderly, veterans (and families) and the disabled. The diverse public health programs such as, free medical care for low income population, children under 12 years of age, the elderly, and the disabled, as well as the health card project have been introduced with the aim to reduce an inequity of care due to the unequal income distribution. Those health programs tend to increase the health costs for Thailand and require more health care resources, including manpower and health facilities, to contend with an increasing demand for health care in Thailand.

When Thailand first determined the 5-year socio-economic development plan in 1961, the first 5-year public health development plan also simultaneously established. From the first public health development plan (1961-1966) to the current eighth plan (1997-2001), one of the essential policies is directed to an attempt to alleviate an inequality of number of health facilities and health manpower in most regions of the country. For almost 40 years, however, the aim to increase the number and efficiency of health facilities and health manpower is still one of the targets.

Health Expenditure in Thailand

Thai health care system has played an important role in economic system during the last decade due to an increasing demand for health care as shown by rising health expenditures (Table 1). Although the Thai medical care system has not yet experienced a persistently high level of expenditure (only 3 to 5 percent of GNP) as compared to around 10 percent of GNP in some industrialized nations, the Ministry of Public Health (MOPH)' s budget has constantly increased from 166 million US$ in 1982 to 1,128 million US$ in 1995.

Table 1 shows that health expenditure in Thailand at 1988 prices increased about 298 percent from 40,057 million Baht in 1980 to 159,367 million Baht in 1995. The sudden shift in a percentage change of health expenditure in 1984 was due to the capital investment resulting from the Fifth National Development Plan (1982-1986) aiming at an expansion of the coverage of health facilities in district areas. Furthermore, as shown in Table 1, total health expenditure in real terms during 1983 and 1988 had been steadily rising at a higher rate than the growth of GNP. And from 1980 to 1995, while the GDP increased at the rate of 8.11 percent on average, total health expenditure increased faster at the rate of 9.74 percent on average. In Table 1, the proportion of GDP spent on health during 1980 and 1990 also increased. And total health spending, as measured against Thailand's gross domestic product, increased from 4.38 percent in 1980 to 5.43 percent in 1995.

Table 1 Health expenditure in millions of Baht and share of health expenditure as a percentage of GDP at 1988 Prices, 1980-1995.

Year	Total Health Expenditure	% Change Health Expenditure	% Change GDP	% of GDP on Health
1980	40,057	-	-	4.38
1981	44,778	11.78	5.91	4.63
1982	46,887	4.71	5.35	4.60
1983	53,628	14.38	5.58	4.98
1984	64,002	19.34	5.75	5.62
1985	71,301	11.40	4.65	5.98
1986	76,974	7.96	5.53	6.12
1987	86,500	12.37	9.52	6.28
1988	100,311	15.97	13.29	6.43
1989	111,252	10.91	12.19	6.36
1990	119,755	7.64	11.17	6.15
1991	123,154	2.84	8.56	5.83
1992	130,280	5.79	8.08	5.71
1993	139,515	7.09	8.38	5.64
1994	144,208	3.36	8.94	5.35
1995	159,367	10.51	8.83	5.43
avg.	-	9.74	8.12	-
std.dev.	-	4.72	2.66	-

Source: Adapted from the National Income Account, the Office of the National Economic and Social Development Board (NESDB),Thailand.

Private Health Expenditure

In Table 2, from 1980 and 1995, the percentage change of private health expenditure varied from 2.43 percent to 21.84 percent, with a mean of 9.88 percent. Compared with other private sector expenditures spent on basic needs in the same period, such as food and clothing, the mean percentage growth of private health expenditure was somewhat higher than that on food and clothing – an average of 3.12 percent and 7.89 percent on food and clothing, respectively. Health and personal care increasingly becomes the leading competitive category of household expenditures.

Table 2 Percentage change of private health expenditure, food and clothing, 1980-1995.

Year	Private Health Expenditure[a]	Food Expenditure	Clothing and Personal Effects Expenditure
1980	-	-	-
1981	11.21	1.75	9.16
1982	3.25	0.33	5.96
1983	14.03	1.59	6.97
1984	21.84	-0.77	5.03
1985	11.44	4.61	4.87
1986	9.32	0.26	4.54
1987	13.68	1.98	11.34
1988	17.41	4.52	7.46
1989	11.53	6.13	12.53
1990	8.29	2.39	15.69
1991	2.43	2.71	7.57
1992	5.33	6.01	7.22
1993	5.20	4.61	5.47
1994	2.73	5.34	6.73
1995	10.56	5.31	7.86
avg.	9.88	3.12	7.89
std.dev.	5.57	2.25	3.13

[a] Personal Care and Health Expenses

Source: Adapted from the National Income Account, the Office of the National Economic and Social Development Board (NESDB),Thailand.

Public Health Expenditure

Table 3 Percentage change of public health expenditure, general administration, defence, justice and police, education and research, transportation and communication and social welfare services, 1981-1995.

Year	Public Health Expenditure[a]	General Admin.	Defence	Justice and Police	Educ. and Research	Trans. And Comm.	Social Welfare Services
1981	15.08	19.09	18.31	9.86	9.10	12.11	5.98
1982	12.76	-8.27	-5.41	10.11	15.04	-1.78	17.26
1983	16.11	3.01	4.06	9.77	7.51	-8.30	-2.77
1984	6.96	3.50	10.30	7.01	10.16	-5.17	14.84
1985	11.17	3.02	9.58	12.19	6.08	-7.63	0.39
1986	0.22	-0.70	-7.60	-7.21	6.93	7.51	15.99
1987	4.32	0.29	-0.30	-5.63	1.74	-4.15	2.02
1988	6.24	3.57	1.92	2.98	5.07	13.11	1.54
1989	6.28	6.90	-4.16	5.42	4.30	1.94	40.26
1990	2.59	5.27	12.21	2.96	6.01	4.02	-18.90
1991	6.18	6.53	5.38	11.59	5.76	-3.76	8.18
1992	9.42	6.17	6.93	10.59	2.78	13.31	-1.23
1993	21.56	10.07	-6.69	7.93	9.73	-14.57	12.64
1994	7.54	10.91	11.52	5.09	1.95	33.85	13.52
1995	10.21	-0.28	3.23	12.85	8.04	-7.05	27.37
avg.	9.11	4.61	3.95	6.37	17.11	2.23	9.14
std.dev	5.57	6.18	7.73	6.07	62.32	12.20	13.91

[a] Health services

Source: Adapted from the National Income Account, the Office of the National Economic and Social Development Board (NESDB),Thailand.

Table 3 shows that from year 1980 to 1995, the percentage change of public health expenditure had been positive at a rate varied from 0.22 percent to 21.56 percent, with an average of 9.11 percent. The allocation of public expenditures on general administration, defense, justice and police, education and research, transport and communication facilities and social welfare services also increased on average during the same period. In addition, while public expenditure on general administration, defense, justice and police, social welfare services and transport and communication facilities has experienced a negative growth in some years, the public expenditure on health and education and research has continuously shown the positive change in the expenditures.

Although, on average, Thai government had spent on education and research and social welfare services from year 1980 to 1995 more than on public health expenditures – at the mean of 17.11 percent and 9.14 percent on education and research and social welfare services, respectively, public health expenditure at 1988 prices increased at a significantly faster pace than public expenditures on education and research – about 263 percent increase in public health expenditure and 162 percent on education and research. Additionally, Thai government average spending on general administration, defense, justice and police, and transport and communication facilities was below that of health expenditure at the rate of 4.61 percent, 3.95 percent, 6.37 percent and 2.23 percent, respectively

Factors of Health Production

Health outcomes are not only affected by the level of health expenditures, but also by the allocation of resources among production inputs. The health care industry is characterized by a labor-intensive technology. The training and use of health professionals are vital variables in identifying the distribution, efficiency, economy, cost and outcomes. Physicians, for example, are known to create a major portion of the demand for their own services (Reinhardt, 1975). As shown in Table 4, from year 1992 to 1995, the population per health manpower had declined for pharmacist. The supply of nurses and midwives relative to population, however, had worsened during the same period. Among health manpower inputs, a number of physicians and dentists as related to population, however, had not yet decreased steadily and significantly.

From Table 5, comparing all health manpower, the percentage change showed that quantities of nursing, dentistry, and pharmaceutical personnel had grown faster than that of physicians while the growth in midwives had lagged behind that of the more expensive physicians. That is, an increase in the ratio of population to nurses and midwife as well as a slow growth of midwife personnel, therefore, imply that Thai health system may move toward the substitution of more expensive health resources (physicians) for less qualified health professional, such as midwives

Table 4 Ratio between population and factors of health production, 1992-1995.

Category	1992	1993	1994	1995
Pop./physician	4,282	4,260	4,165	4,180
Pop./dentist	21,497	20,841	19,677	20,301
Pop./pharmacist	12,448	12,299	10,532	10,104
Pop./nurse	828	788	1,150	1,092
Pop./midwife	5,487	5,517	5,677	6,103

Source Report of Health Resource, the Ministry of Public Health.

Table 5 Percentage Change of Numbers of Medical and Health Professional, 1985-1995

Year	Physician	Dentist	Pharmacist	Nurse	Midwife
1985	-	-	-	-	-
1986	9.41	-3.86	-0.71	5.93	-17.40
1987	1.22	5.23	8.05	3.61	41.14
1988	17.54	13.76	-4.36	4.76	23.65
1989	12.90	26.17	10.42	16.44	2.08
1990	-1.52	8.45	8.97	4.01	-4.91
1991	2.26	5.38	3.96	4.26	-1.98
1992	4.65	10.84	6.37	7.79	-1.19
1993	1.72	4.38	2.43	6.41	0.66
1994	3.44	7.11	18.09	9.40	-1.74
1995	0.59	-2.14	5.24	6.27	-6.08
avg.	5.22	7.53	5.84	6.89	3.42
std.dev.	6.11	8.44	6.22	3.81	16.71

Source: Adapted from Report of Health Resource, the Ministry of Public Health.

The mix of health personnel in the healthcare system can be a very important indicator of the efficient use of resources since these manpower generally have different training cost and wages. Basically, one can generally distinguish between various levels of health personnel, ranging from physicians, who usually offer the most sophisticated services, to auxiliary health workers at the lower end. Considering an overall availability of health services from a distribution between the most qualified personnel (physicians) and less skilled ones (dentists, pharmacists, nurses, technical nurses, auxiliary nurses, midwives and health workers), Table 6 (last column) shows that the average ratio of medical and health personnel to physicians was 9.01. The ratio was rather high as compared to other Asian countries such as Korea, Malaysia, and Philippines. In those countries, their ratios ranged between 4.0 to 6.0 (Griffin, 1992). This could mean that physicians in Thailand are scarce relative to other health workers.

Table 6 Indices of Factors of Health Production 1985-1995

Year	Ratio of Pharmacists to Physicians	Ratio of Nurses to Physicians	Ratio of Midwives to Physicians	Ratio of Medical and Health Personnel to Physicians [a]
1985	0.39	3.24	0.89	9.44
1986	0.35	3.14	0.67	8.68
1987	0.37	3.21	0.94	9.41
1988	0.31	2.86	0.99	8.75
1989	0.30	2.95	0.89	8.35
1990	0.33	3.12	0.86	8.76
1991	0.33	3.18	0.83	8.74
1992	0.34	3.27	0.78	8.83
1993	0.35	3.42	0.77	9.02
1994	0.39	3.62	0.73	9.35
1995	0.41	3.83	0.68	9.77
Avg	0.35	3.26	0.82	9.01
std Dev.	0.04	0.28	0.10	0.42

[a] Medical and health personnel are dentists, pharmacists, nurses, technical nurses, auxiliary nurses, midwives and health workers.

Source: Adapted from Report of Health Resource, the Ministry of Public Health

In Table 6, the distribution of physicians relative to each category of health personnel in the Thai health system also showed a wider variation. The breakdown of categories suggests the substitution of nurses and pharmacists to physicians and the substitution of midwives for physicians during year 1989 to 1995. The numbers are quite consistent with Table 4, Table 5, and a health delivery system which generally emphasizes a primary health care. Commonly, a small community hospital may have 2-3 physicians with 30-40 nurses. In Thai health system, nurses and pharmacists can substitute for physicians to some extent such as in diagnosing and prescribing for self-limiting illnesses e.g. cold and fever and the training cost and wages for nurses and pharmacists are also tremendously lower.

Table 7 Ratio between population and factors of health production (selected) in Bangkok Metropolis and other provinces, 1992-1995

Category	1992	1993	1994	1995
Pop./physician				
Bangkok Metropolis	909	900	940	999
Other provinces	7,148	7,055	6,510	6,245
Pop./dentist				
Bangkok Metropolis	4,157	4,183	4,561	5,179
Other provinces	39,112	36,079	30,174	29,138
Pop./pharmacist				
Bangkok Metropolis	2,066	2,049	2,320	2,280
Other provinces	27,212	26,195	16,763	15,656
Pop./nurse				
Bangkok Metropolis	332	321	356	347
Other provinces	987	932	1,501	1,407
Pop./midwife				
Bangkok Metropolis	14,753	14,690	15,036	17,762
Other provinces	5,139	5,174	5,329	5,713

Source: Report of Health Resource, the Ministry of Public Health.

Variations in the distribution of the major health professions in Bangkok metropolis and other provinces are shown in Table 7. Health manpower were distributed very unevenly. Bangkok Metropolitan had a considerably lower ratio of population per all health personnel except midwives. Past research (Wennberg, 1984) showed that variations in physician supply have an important effect on the patterns of practice regarding the rates of specific procedures completed by physicians, such as hysterectomy rates, prostatectomies, tonsillectomies, and other common surgical problems. The different ratios explained that Bangkok Metropolis is particularly attractive to health professions with the exception of midwives.

In 1996, an average of 66 percent of the hospital and medical establishments with beds on general services was in the public sector. On the other hand, about 62 percent of the hospital and medical establishments with beds on specialized services was private establishments which concentrated in Bangkok metropolis and municipality. And for health institutions with no admission such as health centers and clinics, private sector consumed a proportion of almost 53 percent in year 1996. The supply of beds relative to population had improved during 1992 to 1995. However, in Table 8, the population-to-bed ratios in Bangkok metropolis compared to other provinces showed poor distribution of health facilities and beds in the country. The ratios depict that hospital and medical facilities are built and in cities rather than in the rural areas.

Table 8 Ratio between population and beds for general services, 1992-1995.

Category	1992	1993	1994	1995
Whole country	691	666	628	501
Bangkok metropolis	282	260	249	221
Other Provinces	819	800	747	576

Source: Report of Health Resource, the Ministry of Public Health.

The geographic maldistribution of average number of health professions and facilities per 1,000 population during year 1982 and 1994 is shown in Table 9. Northeast region has the lowest ratio of all types of health professions, beds, and health facilities with beds per 1,000 population, and Bangkok province has the highest. The *F* test is then used to test the hypothesis of no difference among mean values for all categories in four regions and Bangkok. The results showed that the ratios for all selected factors of production in all regions and Bangkok are different with statistical significance at the 0.01 level.

Table 9 Average number of health profession and facility per 1,000 population by regions for year 1982-1994

Category	*F*-value	Region				
		North	Central	Northeast	South	Bangkok
Beds	188.367	1 338	2.231	0.808	1.496	3.714
health facilities (with beds)	89.261	0 017	0.026	0.013	0.021	0.028
Physicians	258.822	0.182	0.193	0.075	0.139	0.909
Dentists	232.770	0.017	0.035	0.011	0.020	0.187
Nurses	246.701	0.456	0.729	0.259	0.533	2.380
Pharmacists	819.124	0.027	0.044	0.014	0.030	0.481

Source: Report of Health Resource, the Ministry of Public Health.

Geographic variations in distribution of health manpower and facilities can also be explained using *t*-test (Tables 10 – 15). The mean of beds and facilities per 1,000 population is statistically significantly different among regions. However, there is no significant difference of the mean of the health profession per 1,000 population ratios in the North and the South regions. This holds similarly for the ratios of dentist per 1,000 population between the Central and the North and between the Central and the South.

The phenomenal growth in the levels of private and public expenditures on health as compared with other private and public spendings, and in the factors of health production, therefore, raises warning flags: will expenditure be increased, and is efficiency correctly defined and applied to the deployment of resources currently devoted to health? The fact that a low or high percentage of GDP spent on health care does not tell us about the efficiency highlights the need to measure efficiency. This is because measurement of the efficiency on health services would encourage the promotion of a better allocation of health care resources and contain costs. From an economic perspective, perhaps the most relevant consideration is that these personnel are generally paid different wages and cost differentials exist in their training. Thus, the choice of different mixes of health personnel is important in the efficient use of resources. In other words, the efficiency of healthcare system depends on the appropriate level of use of healthcare resources. An efficient allocation of health care resources to and within health care sectors minimizes the social cost of illness, including its treatment. Therefore, a focus on a production function of health care with health care resources as inputs could be insightful and valuable for assessing the efficiency of Thai healthcare system. Despite the growing importance of health care sector in competing for resources and influencing the population health, no empirical studies has explicitly acknowledged the efficiency of health care in most Asian countries including Thailand.

Table 10 *t*-test for differences of the ratio of bed per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		12.033***[a]	7.262***	5.940***	-8.799***
Northeast			-9.685***	-12.208***	-22.775***
North				-2.410**[b]	-18.007***
South					-16.720***
Bangkok					

[a] statistically significance at 99 percent confident level.

[b] statistically significance at 95 percent confident level.

Table 11 *t*-test for differences of the ratio of dentist per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		5.288***[a]	3.706***	2.731**	-14.931***
Northeast			-2.615**[b]	-2.759**	-18.757***
North				-0.810	-17.918***
South					-17.055***
Bangkok					

[a] statistically significance at 99 percent confident level.

[b] statistically significance at 95 percent confident level.

Table 12 *t*-test for differences of the ratio of physician per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		7.708***[a]	3.472***	3.025***	-15.714***
Northeast			-4.089***	-5.502***	-19.186***
North				-0.699	-17.428***
South					-17.323***
Bangkok					

[a] statistically significance at 99 percent confident level.

Table 13 *t*-test for differences of the ratio of facility per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		18.657***[a]	12.063***	6.673***	-1.996*[c]
Northeast			-5.679***	-11.312***	-13.111***
North				-5.284***	-9.588***
South					-6.257***
Bangkok					

[a] statistically significance at 99 percent confident level.

[b] statistically significance at 95 percent confident level.

Table 14 *t*-test for differences of the ratio of nurse per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		6.427***[a]	3.268***	2.334**	-16.548***
Northeast			-3.746***	-5.153***	-27.868***
North				-1.156	-22.373***
South					-21.394***
Bangkok					

[a] statistically significance at 99 percent confident level.

Table 15 *t*-test for differences of the ratio of pharmacist per 1,000 population among regions.

	Central	Northeast	North	South	Bangkok
Central		2.674**[b]	1.456	1.147	-30.444***
Northeast			-3.037***[a]	-2.900***	-48.831***
North				-0.478	-45.506***
South					-42.670***
Bangkok					

[a] statistically significance at 99 percent confident level.

[b] statistically significance at 95 percent confident level.

II. Literature Review

During the last decade, policy and decision makers have become more aware of the scarcity of resources available in health sector. Accordingly, in order to design and determine an effective and efficient health policy in either developed or developing countries, several important healthcare related issues such as healthcare expenditure, equity of care, quality and efficiency have been urgently proposed and investigated. Especially for the efficiency of care aspect, it is widely believed that the efficiency of care provided also implies quality, equity and cost of care. As a result, an evidence on the increasing proportions of healthcare expenditure and an inadequate health financing in many industrialized nations and developing countries brings about a need to explore the efficiency of health systems. The heavy emphasis on efficiency thus characterizes much of the work on health sector reform. (Murray, C.J.L., 1995). Furthermore, for most low-income countries, the health system problem is not only the constrained financial resource, but also equity, efficacy and efficiency of those limited resources such as capital and manpower. The determinants that cause the inefficiency, therefore, must be identified before any health reform strategies can be proposed.

Health sector reform is the process of improving the performance of existing systems and of assuring their efficient and equitable response to future changes (Berman, 1995). Past research on health care reform are closely related to the efficiency. Their relationship can be described as a reciprocal link. That is, in some countries, inefficiency brings about the need to reform health system. On the other hand, for some nations, the objective of the health reform is to generate or improve efficiency in the health system or the provision of care.

Australian government and health service ministers in the 1990s, for example, endeavored to increase production efficiency of hospital services in response to an increasing demand for services during the economic recession. One of the strategies is to introduce pilot scheme like those in the United Kingdom and the Netherlands. The strategy was believed to promote competition which will finally enhance efficiency and accountability in the use of resources (Shiell, 1992).

During the 1980s, Swedish health system also confronted the inefficiency resulting from the increasing cost, excess demand and increasing dissatisfaction. The inefficiency thus gave rise to the introduction of health care reform in the form of social market in the 1990s (Diderichsen, 1995). Similarly, the 1974 comprehensive health plan and the 1987 pro-competitive national health insurance program which introduced in the Dutch health care system had the objectives of cost containment and efficiency improvement with universal access through central reallocating financing (Schut, 1995). In addition, the goal of the reform of the United Kingdom National Health Service (NHS) which has been introduced since 1991 is to improve the efficiency of the resource allocation by creating competition on the supply side of health care market (Maynard, 1994).

One of the problems in Russian health system which contributes to the regional economic experiments in 1988 is the lack of incentives that could promote provider's efficiency. Prior to the reform, the Russian medical care provision is inefficient and has poor health outcomes which are caused by financing and management problems. The health system was then restructured and provision of care is more efficient after the regional experiments (Sheiman, 1995).

In sub-Saharan Africa, the inefficiency in the use of resources and inappropriateness priorities, budget constraint, and poor management of health care system resulted in the restructuring of the health system (Sahn and Bernier, 1995). For instances, due to an intensely limited budget for public health services in Nigeria during the 1980s, the Federal Ministry of Health in Nigeria had to reevaluate the cost and efficiency of the public and private sectors. The survey of health care facilities in Ogun State in 1987 proposed that the service delivery can be increased within existing budgets by using a more cost-effective allocation of inputs as well as a cost-minimizing combinations of high- and low-level health workers (Wouters, 1993).

Efficient allocation and use of resources will result in a high quality and effective service which has maximum impact on health status (World Health Organization, 1993). The questions of technical efficiency, however, often involve the best combination of health inputs, i.e., labor and capital inputs in order to guarantee the quality and low cost health services. Therefore, the efficiency of any health care system significantly depends on an appropriate level of health manpower and capital. Measurement of the efficiency of health system would, then, aid the promotion of a better allocation of health care resources.

Evidence on the study of the efficiency on health care system appeared in many developed countries and developing countries. Nevertheless, several Asian countries including Thailand have not yet explored the investigation of efficiency measurement. Various past research on the health care efficiency employ translog function, stochastic frontier estimation (SFE) and data envelopment analysis (DEA) as tools for efficiency investigation. The SFE and DEA have been widespread recently in various studies (Hollingsworth and Parkin, 1995), the limitations of the models and potential use of the results of those methods are still under debate (Dor, 1994; Hadley and Zuckerman, 1994; Kooreman, 1994; Newhouse, 1994; Skinner, 1994; Vitaliano and Toren, 1994).

Examples of efficiency studies include the study on efficiency of hospital services in Belgium using stochastic frontier estimation (SFE) of resource function which is defined as the relationship between medical fees incurred in the treatment of a patient and the patient's pathology (Bosmans and Fecher, 1995), the investigation of the efficiency of hospital services in the United Kingdom NHS by Scott and Parkin (1995) utilized translog cost function, the analysis of the efficiency of U.S. hospital pharmacies exercised the translog cost function (Okunade, 1991; Okunade, 1993; Okunade and Suraratdecha, 1996), the study of Florida hospital efficiency by estimating the short-run generalized multiproduct translog cost function in order to determine the relationship between cost and level of indigent care (Campbell, 1990), the examination of the effects of medical staff physician on hospital production employed a translog production approach (Jensen and Morrisey, 1986) as well as the measurement of Norwegian hospital efficiency by Magnussen (1996) using Data Envelopment Analysis (DEA) which is a linear programming technique that provides information on the combinations of inputs and outputs and the relative performance of each institution or unit as compared to others.

As the matter of fact, the efficiency can also be investigated either by the production function or cost function due to the merit of the property of duality between production and cost analysis. Most research, however, have chosen the approach of cost function because the input prices are more likely to be independent of the error term in the model. However, when data on input prices are unobservable, the direct estimation of production function appears to be the better choice without bringing in the specification bias arising from treating the inputs as variable or fixed factors. Past research on health production function are assorted. Kenkel (1995) utilized the health production function in examining the important lifestyles for the U.S. adult health. A child health production function for Bangladesh was estimated using the 2SLS fixed effect model to see how parents' schooling affects child health through its interaction with childcare time (Bishai, 1996). Desai (1987) estimated the health production function for the U.S. low-income working men who are medically indigent and explained the impact of medical, preventive and curative care as well as socioeconomic variables on the health production of the low-income men. Jensen and Morrisey, (1986) examined the effects of medical staff physician on hospital production employed a translog production approach The production function for acute hospital was estimated by Feldstein (1967) for studying economies of scale, optimum input proportions, and productive efficiency measurement. Reinhardt (1972) assessed the effect of the quantities of inputs used by the physicians on the physician's average productivity by investigating the production function for physician services.

The evidence of an employment of transcendental logarithmic model in production and cost functions is extensive. Translog model is the well-known technique for analyzing the production process in many sectors, especially the agricultural sector (Berndt and Christensen, 1973; Christensen, Jorgenson, and Lau, 1973). The applications of translog model is also prevailing in the research areas of manufacturing industries (Jha, et. al., 1992; Wang, 1995), banking and finance (Cummins and Weiss, 1993), human resources (van Soest, 1995), and health and pharmaceutical care services (Campbell, 1990; Jensen and Morrisey, 1986; Okunade, 1991; Okunade, 1993; Okunade and Suraratdecha, 1996; Scott and Parkin ,1995), etc. The gain of much popularity in the use of translog function is due to its highly flexibility and reliable result (Guilkey, Lovell, and Sickles, 1983) which stemmed from the relaxation of the assumption imposed on returns to scale and the elasticity of factor substitution among factors of production that equals to one in the Cobb-Douglas function (Greene, 1990). The translog production function has been extensively used to investigate productive efficiency (Greene, 1980; Martin and Page, 1983), input substitution (Berndt and Christensen, 1973), separability and aggregation (Denny and Fuss, 1977), technical change and productivity growth (May and Denny, 1979).

Consequently, in corresponding to the data availability of Thai health care sector and lack of past research on efficiency of health system, the attempt to measure the efficiency of Thai health care by utilizing the production function approach is then proposed in this study. The study is also intended to benefit from the effective translog production function model in (i) analyzing efficiency of Thai healthcare services, (ii) scrutinizing the impact of health resources on people health, (iii) studying the possibility of substitution among health manpower and finally (iv) measuring the economies of scale. The structure of the study is as followed. Section 3 describes the model, data and analytical method used in the study. The results are presented in Section 4. Section 5 contains concluding remarks and recommendation.

III. Model, Data and Analytical Method

Model

The model specification employed in this study is a translog production function, which is a second-order Taylor series approximation to an arbitrary production function that is twice-continuously differentiable. The production function represents a tool for analyzing how different resources such as doctors, nurses, pharmacists, and beds can be combined to produce health services (output). The degree of substitutability between different types of resources or health manpower derived from the production function is important to determine since it provides information the policy- and decision makers need to know in order to minimize the cost of providing effective and efficient health care. Utilizing the translog which is a flexible functional form, therefore, allows the estimated functions to thoroughly capture the various potential effects of inputs on an output.

The translog function is derived from the generalized power production function, a generalized version of the Cobb-Douglas, introduced by de Janvry (1972) as follows:

$$Q = f(x) = A\prod_{i=1}^{n} x_i^{f_i(x)} \exp g(x),$$

where Q = f(x) is the output, x is the combination of inputs, and $f_i(x)$ is parameter.

This production function becomes the transcendental function which is a progenitor of the transcendental logarithmic function when $f_i = \alpha_i$ and $g(x) = \sum_i \gamma_i x_i$. The translog function, therefore imposes fewer constraints than other functional specifications. The translog does not impose the production structure restrictions regarding returns to scale and elasticity of substitution as other functional forms such as Cobb-Douglas and CES.

Consequently, the relationship between output and inputs in this study can be described as

$$Q = f(x_{i,r,t}, t),$$

where the output of the r^{th} region in period t, $Q_{r,t}$, is specified as a function of time *t*, which is a time index utilized to measure technical change, and its utilization of x inputs in that period.

A translog production function which is nonhomothetic and imposes no restriction on production technology is estimated in this study as the primary equation in the general form:

$$\ln Q_{r,t} = \alpha_0 + \sum_i \alpha_i \ln x_{i,r,t} + \delta_t t + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln x_{i,r,t} \ln x_{j,r,t}$$
$$+ \sum_i \gamma_{it} \ln x_{i,r,t} t + \frac{1}{2}\delta_{tt} t^2 + u, \qquad (1)$$

where $\beta_{ij} = \beta_{ji}$ $(i \neq j)$, u is a random disturbance assumed to be identically and independently distributed (i.i.d), and α, β, δ and γ are parameters.

Since the translog function requires the estimation of a large number of parameters, the estimation of factor share equations together with the parent production function as a system equation then reinforces the efficiency of estimation due to an increase in the degree of freedom. Of the i relevant factor share equations, any i - 1 are independent because the sum of the factor shares all inputs is equal 1 and disturbances sum identically to zero. One of the share equations is then deleted during estimation to avoid the singularity in the error-covariance matrix. As a result, the system of the translog production function and i - 1 share equations will be estimated so that the parameters can be effectively computed due to an increase in degree of freedom.

Data and Analytical Method

The data are collected from various sources: Health Resources Report (various years), the Ministry of Public Health, Thailand, Public Health Statistics (various years), the Ministry of Public Health Thailand, and Thailand Statistics Yearbook (various years), National Statistical Office, Thailand. The data set is annually aggregated by region from year 1982 to 1997. These regions include Central, North, Northeast, South and Bangkok metropolis. The data of health inputs and output on 16 years of observation for each of the five regions, therefore, making a total of 80 observations.

The data series for each region in this study consist of (i) four factor variables- number of medical doctors (M), number of pharmacists (P), number of nurses (N) and number of beds (B), (ii) time (T) to capture the technological progress, (iii) number of population (POP) to represent patients which are the input used to produce health and (iv) number of health establishments with beds (H) to measure a capacity of health care system in producing health. The medical doctors, pharmacists and nurses variables included only full time active staffs (8 hours). The nurses are professional nurse, nurse practitioner nursing and midwifery, public health nurse, anesthetic nurse and nurse specialist. Beds are used as a measure of capital in the health care system. Feldstein (1999) concluded that no single measure of health could adequately represent the concept of health status. On an aggregate level, available health measures (such as births and deaths) are collected by government agencies as part of vital statistics, which tend to be more accurate than others. The number of livebirths per 1,000 populations (Q) in each region during the same period of time is then used as a proxy for the measure of output in order to avoid the negative interpretation of health production. Table 16 reports descriptive statistics on each variable.

Therefore, from equation (1), the translog production function model for this study then becomes:

$$\begin{aligned}
\ln Q = {} & \alpha_0 + \beta_M \ln M + \beta_P \ln P + \beta_N \ln N + \beta_B \ln B \\
& + \frac{1}{2}\gamma_{MM}(\ln M)^2 + \gamma_{MP} \ln M * \ln P + \gamma_{MN} \ln M * \ln N + \gamma_{MB} \ln M * \ln B + \frac{1}{2}\gamma_{PP}(\ln P)^2 \\
& + \gamma_{PN} \ln P * \ln N + \gamma_{PB} \ln P * \ln B + \frac{1}{2}\gamma_{NN}(\ln N)^2 + \gamma_{NB} \ln N * \ln B + \frac{1}{2}\gamma_{BB}(\ln B)^2 \\
& + \theta_T \ln T + \frac{1}{2}\theta_{TT}(\ln T)^2 + \theta_{TM} \ln T * \ln M + \theta_{TP} \ln T * \ln P \\
& + \theta_{TN} \ln T * \ln N + \theta_{TB} \ln T * \ln B \\
& + \delta_H \ln H + \frac{1}{2}\delta_{HH}(\ln H)^2 + \delta_{HM} \ln H * \ln M + \delta_{HP} \ln H * \ln P \\
& + \delta_{HN} \ln H * \ln N + \delta_{HB} \ln H * \ln B \\
& + \omega_{POP} \ln POP + \frac{1}{2}\omega_{POPPOP}(\ln POP)^2 + \omega_{POPM} \ln POP * \ln M + \omega_{POPP} \ln POP * \ln P \\
& + \omega_{POPN} \ln POP * \ln N + \omega_{POPB} \ln POP * \ln B + \varepsilon, \qquad (2)
\end{aligned}$$

where ε is an error term, and α, β, γ, θ, δ and ω are parameters.

The restrictions for symmetric cross-coefficients and homogeneity conditions are imposed in order to be consistent with economic theory as follow:

$\gamma_{ij} = \gamma_{ji}$ for all the i^{th} and j^{th} inputs. (3)

$\sum \beta_i = 1$, $\sum_j \gamma_{ij} = 0$ for all the i^{th} inputs. (4)

Table 16 Descriptive Statistics.

Variable	Definition	Mean	Standard deviation
Q	Number of livebirths.	191,655.91	70,253.52
M	Number of full-time active physicians.	2,323.78	1,735.86
P	Number of full-time active pharmacists.	847.50	958.36
N	Number of full-time active nurses (including professional nurse, nurse practitioner nursing and midwifery, public health nurse, anesthetic nurse and nurse specialist).	7,568.46	4,120.61
B	Number of beds.	18,077.70	6,508.76
H	Number of hospital and medical establishments with beds.	206.46	65.81
POP	Census population.	10,505,957.99	4,983,633.31

The system of production function (equation (2)) and 3 of the 4 factor share equations were simultaneously estimated jointly using the efficient Zellner's iterative 3SLS SURE procedure in SAS in order to obtain asymptotically efficient maximum likelihood parameter estimates that are also invariant to which share equation is deleted at the second stage of estimation. The translog production function was estimated as an unrestricted system by imposing the symmetry restriction in (3) and homogeneity in inputs restriction in (4) for a specification test. All variables are normalized by dividing each variable by its mean before taking logarithms , i.e., the second order approximation with the expansion at the mean of the data. The efficiency, marginal product, elasticities of factor substitutions, technological change and economies of scale are then respectively estimated.

The Allen partial elasticity of substitution is defined by

$$\sigma_{ij} = \frac{\sum_i x_i f_i}{x_i x_j} \frac{F_{ji}}{F},$$

where i and j are inputs, F is the bordered Hessian determinant and F_{ij} is the cofactor associated with f_{ij}.

The Morishima elasticity of substitution is defined by

$$\sigma_{ij}^{M} = \frac{f_j}{x_i}\frac{F_{ij}}{F} - \frac{f_j}{x_j}\frac{F_{ij}}{F}$$

which is non-symmetric and has implications for the classification of inputs as substitutes and complements.

And

$$\sigma_{ij}^{M} = \frac{f_j x_j}{f_i x_i}(\sigma_{ij} - \sigma_{jj}).$$

IV Empirical Results

Productivity Growth and Growth of Inputs and Output

Table 17 provides the productivity growth with respect to each input for each period of development plan and for years 1982 to 1997. The productivity for each input is calculated by total output divided by input. All factors had the negative productivity growths. The data used in this study cover 3 periods of health development plans. The calculated productivity growth from table 17 reflects the poor performance and wrong direction of public health development plan, especially for the 5th health development plan (1982-1986), in aiming at increasing the number of health resources. The consecutive development plan (the 6th and 7th plans) resulted in better performances in terms of productivity of each factor except for pharmacist and bed.

Table 17 Percentage change of productivity growth for each factor.

Period	Physician	Pharmacist	Nurse	Bed
1982-1986	-30	-19	-34	-24
1987-1991	-19	-9	-18	-14
1992-1996	-14	-15	-16	-21
1982-1997	-63	-57	-67	-60

Table 18 Growth of inputs and output (%)

Period	Physician	Pharmacist	Nurse	Bed	Livebirth
1982-1986	26	8	33	16	-12
1987-1991	34	20	32	26	9
1992-1996	21	22	24	32	4
1982-1997	125	92	151	110	-17

These productivity growth rates related to the percentage growth of inputs and output in Table 18. The growth of physicians is slowdown during the 7th plan whereas the growth of pharmacists and beds, however, increases at an increasing rate in every development plan. Nurses' growth also increases at a decreasing rate during all three development plans. The output growth, on the other hand, declined during the 5^{th} plan. The decline was recovered during the 6^{th} and 7^{th} plan, however, still at the very slower rate than those of input growths were.

Estimation of Health Production Function

The estimated parameters of the health production function are presented in Table 19. The equation system weighted R^2 is 74.44 percent with system weighted MSE of 1.3905 with 289 degrees of freedom and 80 observations. The first-order parameters of factors are all significant at the 1 and 5 (for pharmacists only) percent levels and have positive signs except for physicians and pharmacists, indicating that an increase in the number of nurses or beds brings about an increase in output whereas the rise in the number of physicians and pharmacists causes a decrease in the number of livebirths. The second order estimates are small and only the second-order estimates for pharmacist and bed are statistically significant.

It is quite interesting to note that the interaction terms between inputs are significant. This suggests that the health production function, which either contains only the first order term or has no cross-product term, may not be appropriate. The negative sign and statistical significance of the coefficients for interaction terms for physicians and other types of inputs indicate that physicians can decrease the productivity of pharmacists and population. The fact that physicians at clinics, the growing and convenient health facilities, can simultaneously diagnose and treat patients with medicine without pharmacists may be the explanation for this relationship. In contrast, physician has a significant positive effect on the productivity of nurse, technology and hospital. This may reflect the tendency for physicians to associate with more nurse, technology and hospital in producing health output.

Nurses and beds, on the contrary, decrease the productivity of technology in producing health output. The coefficient of the census population (POP and POP*POP) is also strongly and significantly different from zero and positive, suggesting that number of population or patients is increasingly efficient in turning health care inputs into output. Although our early analysis showed that there is an evidence of maldistribution of health personnel among regions, our attempts to investigate the differences of input efficiencies for those regions did not succeed due to severe multicollinearity.

Table 19 Estimated translog production function

Variable (in log)	Coefficient	Standard Error	Variable (in log)	Coefficient	Standard Error
Intercept	0.157**	0.062	M*B	0.033	0.022
M	-0.482***	0.047	M*T	0.199***	0.021
P	-0.134**	0.059	M*H	0.746*	0.404
N	0.651***	0.038	M*POP	-0.552**	0.267
B	0.965***	0.052	P*N	-0.014	0.016
T	-0.419***	0.061	P*B	0.030	0.024
H	0.488**	0.203	P*T	0.036	0.024
POP	0.452***	0.146	P*H	0.313	0.236
M*M	0.001	0.027	P*POP	0.224	0.173
P*P	0.067*	0.033	N*B	0.020	0.037
N*N	-0.054	0.033	N*T	-0.306***	0.017
B*B	-0.083**	0.032	N*H	-0.918	0.614
T*T	0.114***	0.022	N*POP	-0.358	0.392
H*H	1.054***	0.351	B*T	-0.443***	0.024
POP*POP	0.285***	0.082	B*H	-0.074	0.516
M*P	-0.083***	0.023	B*POP	-0.053	0.259
M*N	0.048*	0.025			

***, **, * Statistical significance at the 0.01, 0.05, 0.1 levels respectively.

Marginal Product, Technical Change and Economies of Scale

Normalization of the variables generates the convenience that the first-order parameters are elasticities when evaluated at the means. Furthermore, the interaction terms between each pair of factors were dropped out in evaluating the impact of a change in input on output if they are evaluated at the means. Therefore, the estimated factor coefficients demonstrate the percentage change in output as the factor changes by one percent. The marginal product of each input is given by

$$MP_i = \beta_i \times \frac{Q}{X_i}.$$

From the mean values, this implies that an increase in the number of factors by one unit will be associated with an additional output, i.e., the marginal product as indicated in Table 20.

Table 20 Marginal product

Factor	Marginal product
Physician	-39.753
Pharmacist	-30.303
Nurse	16.485
Bed	10.231

The production function shows that marginal products for nurses and beds are positive whereas those for physicians and pharmacists are quite large and negative. That is, the Thai health system may be subject to the size effect, especially for the physician and pharmacist. Adding a physician and a pharmacist to the health system reduces 39.753 and 30.303 livebirths per 1,000 population per year. Therefore, as the number of physicians and pharmacists increases, the marginal products of physicians and pharmacists decline. As more and more physicians and pharmacists also have teaching and management duties in the health facility establishments as well as other the Ministry of Public Health's affiliations, this will tend to decrease the productivity in health production activities. Moreover, the tendency that more and more physicians are likely to seek training as specialists, which may lead to the reduction of the case load, will reduce measured productivity in patient care activities. Since the physicians and pharmacists have negative marginal productivity and net contribution when all coefficients associated with physicians are taken into consideration, physicians and pharmacists are therefore non-productive.

On the other hand, the marginal product for nurses of 16.485 is higher than that of beds implies that the nurses have a more significant role in producing health output. This is because physicians have a strong impact on the productivity of nurses The nurse is consequently the most productive health input in this case

The marginal product for beds of 10.231 means that adding one more bed then has a positive effect on the health output of 10.231 livebirths per thousand of population.

A positive relationship between the output and technology progress, however, is statistically significant at the 1 percent level representing the technical change. Since the technical progress is decreasing at a decreasing rate with a rate of technical change of –0.191, the characteristic of Thai health production then is not a technological driven process. Hospital and medical establishment (H and H* H) which was employed as a measure for capacity to produce health is positive and highly significant indicates that an increase in the health production capacity is associated with an increase in output, possibly reflecting under capacity in health production. That is, Thai health care is produced at the rate of significant scale economies with an elasticity of scale of 2.597.

Elasticity of Substitution

The partial elasticity of substitution for each input pair is calculated in order to investigate the availability of the input substitution possibilities. Both Allen and Morishima elasticities of substitution are reported in Table 21. Elasticity values from either Allen or Morishima calculations give the same results that all inputs are substitutes for each other. Allen elasticity shows that physicians and pharmacists are the two inputs that can be easily substituted as expected. Physicians can also substitute with nurses and beds but at a very lesser degree than with pharmacists. Between beds and nurses, pharmacists can easily substitute with beds than with nurses. Nurses and beds are the factors that can hardest substitute compared to other pairs of inputs. Morishima elasticity, on the other hand, shows that pharmacists and beds are the easiest substituted inputs, followed by the physicians and pharmacists. Like Allen elasticity, Morishima elasticity for nurses and beds has the lowest value.

Table 21 Elasticities of Substitution

Input	Allen elasticity	Morishima elasticity
Physicians and pharmacists	5.46	2.43
Physicians and nurses	1.41	1.63
Physicians and beds	1.54	2.25
Pharmacists and nurses	2.19	1.57
Pharmacists and beds	3.16	3.21
Nurses and beds	1.19	0.36

V. Concluding Remarks and Recommendation

This paper is the first to address the important aspect of health care system in Asia utilizing the translog production function approach. From the empirical results, the more flexible production function for Thai health care is confirmed. The marginal product and estimated coefficients of physicians and pharmacists decrease while those of nurses and beds increase. The findings are the first evidence calling for an investigation of health manpower and resource policy. Moreover, the evidence of factor substitution exists for all 4 types of health inputs in our analysis. Our study, therefore, provides insight into the roles of health manpower and the direction of health policy regarding the health personnel.

The negative values of physicians and pharmacists estimates and marginal productivity, however, contradict to the nation's direction on the attempt to increase the number of health personnel on both physicians and pharmacists as reflected in all Health Care Development Plan. The effort came from the lack of personnel in the rural areas as well as the unmet targeting ratios. Our results reflected that, at the aggregate level, the contribution of physicians and pharmacists to the health output is at the negative rate. This implies that the problem is left on the management of the allocation and distribution, not the number of personnel.

On the other hand, nurses, who are paid lower than the physicians and have a higher percentage growth in the numbers than the other health manpower, contribute to the health output at the highest rate. Furthermore, while the number of physicians decreases and the number of nurses increases, the ratio of nurses to physicians is on the rise. One physician, on average, needs more nurses than before. That is, there is an evidence of substitution in which is confirmed by the positive value of elasticity of substitution between physician and nurse. The size and sign of marginal product of nurses and the coefficients of the first-order and interaction terms between nurses and other personnel implies that the health policy aiming at increasing the number of nurses is considerable due to nurses' high productivity.

The fact that patients can alternatively seek care and get the medicine from the pharmacists without getting the diagnosis or prescription from the physicians, however, does not reflected in this study. Like physician, pharmacist also has a negative marginal product although less negative. Therefore, adding one more pharmacists will have a negative effect on the health output. The result may stem from the ongoing trend that more pharmacists establish their own drug store or work as salespersons for the pharmaceutical companies, which reduce the direct impact on health output. Nevertheless, the positive elasticity of substitution between physician and pharmacist still shows that both types of personnel can still be substituted. Since the marginal product of physician is more negative than that of pharmacist, more pharmacists should be substituted for physician since in Thailand pharmacists can treat patients for some type and degree of sickness.

That the marginal product of beds is also positive but smaller than that of nurses reflects the high productivity. The positive and significant coefficient of beds implies that more beds will contribute to more health output. The result, however, does not correspond to the report on bed vacancy in the private sector as mentioned earlier. The possible explanation is that when both public and private beds are taking into account in this study, beds become productive. This reflects the low funding for beds in the public sector and too high investment of private health facilities. The negative rate of technical change reflects that more use of technology such as medical devices will not contribute to the output increase. Our result corresponds to the alarm urged by Wibulpholprasert et al (1998). Therefore, the evidently positive trend of medical device acquisition will not make a contribution to Thai health production. The same result is held for hospital that represents the capacity of health care system in our analysis. That is, the increasing number of hospital has a positive impact on the health output.

In conclusion, our study has several implications for the health policy direction with respect to factors of health production. Since all inputs can be substituted, the health policy should pay more attention to the factors that generate more productivity, which are nurses and beds in this case. Although pharmacists and physicians can be substituted, pharmacists should substitute for physicians because pharmacists' marginal product is better. Medical device investment at current rate will not result in better health of Thai population. Also, health policy should direct towards the goal to increase more contribution of health inputs to the health output.

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