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Economies of Scale and Hospital Productivity: An Empirical Analysis of Medical Area Level Panel Data*

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Abstract

This paper estimates the total factor productivity (TFP) of hospitals by using panel data drawn from prefectures and secondary medical areas. The study focuses on the economies of scale at the medical area and hospital levels. It uses the average length of stay as a measure of medical quality. We avoid case-mix bias by using data from medical areas instead of those from the hospital level. We control unobservable regional characteristics by employing panel data estimation. We eliminate price disparities among regions by using quantity data. Our results show that hospital size affects productivity: the larger the hospital, the higher the productivity. The hospital-size effect is economically significant: hospital productivity increases by more than 10% when the size of the hospital doubles. The size effects are null when we do not control the average length of stay. The main policy implication is the clear fact that consolidating hospitals improves productivity.

Key words: hospital, medical area, length of stay, TFP, economies of scale

JEL Classification: D24, I11, L84

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1. Introduction

This paper presents empirical evidence concerning the total factor productivity (TFP) of hospitals in Japan. Japan's healthcare sector is becoming an important part of its economy as its population rapidly ages. National healthcare expenditure in fiscal 2007 was 34.1 trillion yen, or 9.1% of the national income. Healthcare expenditure has been increasing by 1.7% every year since fiscal 1997, while its ratio against national income has increased by 1.5% over the same period. Thus, productivity growth in the healthcare sector significantly impacts Japan's aggregate economic performance.

Many have criticized Japanese hospitals for their high beds-per-population ratio, their too-long lengths of stay, and their small capacity. In fact, OECD statistics from 2007 suggest that Japan's rate of acute care hospital beds per 1,000 people is 8.2, more than twice the OECD average (of 3.8 beds) and the highest rate among all OECD countries (see Figure 1). The average length of stay for acute care in Japan is 19 days, three times longer than the OECD average (of 6.5 days) and the longest among all OECD countries.[1] In fiscal 2008, the cost of inpatient care was 13.2 trillion yen, representing 73.3% of total hospital costs: thus, inpatient-care productivity is the dominant factor in overall hospital productivity. The average length of hospital stay is thought to be a major factor in rising medical costs for the elderly. The "Outline of Medical Care System Reform" (2005), as proposed by the Government mandated that Japan's average length of stay be reduced 4.5 days by 2015.

A number of studies have pointed out that changes in quality must be incorporated in calculating healthcare productivity. Some of the studies that have measured productivity changes in the treatment of specific conditions (such as heart attacks, low birth weight, depression, and cataracts) have indicated that the quality of the medical services has been rapidly improved by technological advances (see, for example, Berndt et al., 2000; Cutler and Berndt, 2001). The Boskin Commission Report, which investigated the upward bias of the U.S. Consumer Price Index (CPI), estimated that the CPI on medical services was overestimated by about 3% per year because the rate had not been properly adjusted for quality changes (see Gordon and Griliches, 1997). The updated estimate by Lebow and Rudd (2003) found that the CPI on medical services still had a 2.3% upward bias. Thus, explicit considerations of quality changes are essential in analyses of the productivity and efficiency of healthcare services.

This paper therefore estimates the TFP of Japanese hospitals by using the shortening of the length of stay as a proxy for quality improvements in medical services. The regional-level panel data used here comes from the Hospital Report and the Survey of Medical Institutions (Ministry of Health, Labour and Welfare). This study focuses on the economies of scale at the hospital and medical area levels in Japan. Morikawa (2009), for example, found significant establishment-level economies of scale for personal service industries, which are larger than those for average-sized manufacturing plants; this result suggests that the expansion of the establishments' size through consolidation may contribute to the productivity growth of the service sector. However, Morikawa's study was limited to a few market services, such as movie theaters, bowling alleys, and fitness clubs. According to Propper and Van Reenen (2010), the UK Government undertook a reconfiguration of hospitals in the late 1990s and early 2000s in order to gain scale economies. We are interested in the potential effectiveness of such a policy on Japanese medical services.

Using micro data at the establishment or firm level is a recent trend in empirical studies on productivity. However, the appropriate treatment of differences in case-mix has been a challenge for researchers studying hospital productivity (see Newhouse, 1994). Hospitals are well known to be quite heterogeneous in their patients and treatments. Using regionally aggregated data is one of the practical ways of controlling the case-mix (see Keeler and Ying, 1996). Japan's "The Medical Care Plan System" identifies "medical area" as the basic regional unit capable of providing various medical services independently. This paper estimates the production functions of hospitals by using data from the prefecture and "Secondary Medical Area" levels. The 47 prefectures usually correspond to the "Tertiary Medical Area," whose medical services include advanced medical treatments, such as those for intractable diseases.[2] The tertiary medical areas are divided into several secondary medical areas. The secondary medical areas are designed to provide inpatient medical services (except advanced medical treatment) self-sufficiently. There were 348 secondary medical areas as of 2008.[3]

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1 OECD Health at a Glance 2009.

2 Hokkaido and Nagano, geographically large prefectures in Japan, are the exceptions, each containing more than two tertiary medical areas.

3 City is the unit of the Primary Medical Area, which provides primary care services.

Our analysis confirms the existence of economies of scale: the larger the hospital, the higher its productivity. Hospital size effect is economically significant: hospital productivity increases by more than 10% when the size of the hospital doubles. This effect cannot be detected without considering the quality of medical care as proxied by the average length of stay. In other words, quality improvements in healthcare services enhance hospital-level economies of scale. This result suggests that the consolidation of small hospitals into larger ones may increase the overall productivity of the healthcare sector.

This paper is structured as follows. Section 2 briefly reviews the literature on the estimation of hospital productivity. Section 3 describes the data employed and the method of analysis. Section 4 reports the estimation results. Section 5 presents conclusions and their policy implications.

2. Related Literature

A comprehensive survey of the numerous studies on the productivity and efficiency of hospitals is beyond the scope of this paper, but we briefly review the related literature. Most studies use the estimation of cost functions and the data envelope analysis (DEA) rather than the estimation of production functions because of the diversity of hospital outputs and inputs. Moreover, studies often employ stochastic frontier analysis (SFA) to estimate cost function. Hollingsworth (2003, 2008) provides a good survey of these methods. Many estimations of cost functions found economies of scale in hospitals (Vitaliano, 1987; Carey, 1997; Li and Rosenman, 2001; Preyra and Pink; 2006, among others). However, many studies do not adequately deal with the case-mix bias and service quality. In addition, the cost-function approach has a disadvantage: pecuniary cost is inevitably affected by the time-series changes in price or price differentials among hospitals or regions.

Most of the prior studies use hospital-level micro data to analyze the performance of hospitals, but controlling the difference in case-mix and service quality among hospitals has been difficult (see Newhouse, 1994). Keeler and Ying (1996) use state-level aggregated data in order to avoid case-mix bias in their analysis of the social cost of excessive bed capacity in the community hospitals. Keeler and Ying assert that “larger hospitals get sicker, more expensive patients, and if case mix indices do not fully capture these effects, then there could easily be a bias towards decreasing returns to scale in the output results," and that "working with state averages avoids this problem." Interestingly, they found a slight *decrease* in returns to scale, with a 1.04 rate of elasticity of cost with respect to volume of patients. Their paper persuasively argues that regional-level data is extremely useful in analyzing the healthcare sector.

Some recent studies investigate scale effects by focusing on specific medical treatments. Gaynor et al., 2005, for example, analyze the relationship between the volume of heart surgery and in-hospital mortality in California. They show that the probability of death due to heart surgery is appreciably lower in high-volume hospitals and that this volume–outcome effect arises primarily through scale economies. Gobillon and Milcent (2010) analyze spatial disparities in heart-attack mortality by using a French matched patients-hospitals dataset. Their results show that an area's mortality tends to be lower when patients in that area are distributed across a few large hospitals rather than many small ones. These outcome-based studies provide important contributions to the literature, but the analyses are limited to specific treatments, and the results cannot be generalized to hospitals as a whole.

Motohashi (2009) is a recent Japanese microanalysis of estimating hospital productivity, but its focus is not on the economies of scale, and its analysis is not free from the case-mix bias. Ito (2010) analyzes the profitability of local government-owned hospitals by using panel data spanning from 2003 to 2007 and indicates that profitability is higher for larger hospitals. However, hospital productivity is not the subject of her study. Ogawa and Kubo (2005) measure the technical efficiency of medical services by DEA. They use data on the secondary medical area level and find that less densely populated areas exhibit higher efficiency scores. However, they do not analyze the economies of scale. In addition, since their analysis occurs on a cross-section basis, unobservable regional characteristics may affect their results.

To summarize, we have not yet found conclusive evidence concerning the effect of hospital size on TFP. Previous studies all suffer from limitations—from case-mix bias, neglect of service quality, insufficient coverage, the influence of price differences, etc. The present paper is an attempt to overcome those shortcomings.

3. Data and Empirical Method

The panel data set used in this paper is taken from the published Hospital Report and the Survey of Medical Institutions. We use both prefecture-level (with 47 prefectures) and secondary medical area level (239 areas) balanced-panel data sets. The sample periods cover 1997 to 2008 for the prefecture-level data and 1998 to 2007 for the secondary medical area data. The geographical boundaries of the secondary medical areas, which are different from the prefectural boundaries, have sometimes changed. There were many boundary changes between 1997 and 1998 and between 2007 and 2008. Therefore, we use a 10-year panel, from 1998 to 2007, for the analyses at the secondary medical area. In addition, we removed all secondary medical areas within the 15 prefectures whose number or boundaries changed between 1998 and 2007. Thus, we use a balanced-panel of the 239 secondary medical areas. As already stated, using regionally aggregated data controls case-mix bias. In this respect, both the prefecture (i.e., tertiary medical area) and the secondary medical area are appropriate units of study, as those areas are designed to provide medical services self-sufficiently.

The Hospital Report, conducted by the Ministry of Health, Labour and Welfare (MHLW), is a survey covering all hospitals nationwide that collects information on the numbers of patients (inpatients, outpatients), physicians, nurses, beds, etc. The MHLW also conducts the Survey of Medical Institutions to collect information on machinery and equipment, the number of healthcare professionals and their working conditions, the number of beds, etc. A detailed survey covering all hospitals in Japan is conducted annually. Since all hospitals are obliged to answer these administrative surveys, the response rates are almost 100%. These surveys define “hospital” as a medical establishment with inpatient facilities for 20 or more patients where medical doctors or dentists provide health care and dental care.[4]

Major variables used as output and input measures in our analysis include the annual total number of inpatient days, the number of beds, the utilization rate of beds, the average length of stay, and the number of physicians (full-time equivalent number). We also use other variables, such as the number of outpatients, the total number of staff members, and the number of hospitals in the region, as additional variables.

[4] A medical care institution with no inpatient facilities or with inpatient facilities for 19 patients or fewer is called a “medical clinic.”

The output measure we use is the annual total (cumulative) number of inpatient days divided by the average length of hospital stay. A longer hospital stay for a given disease will translate into larger output if one simply uses the annual total number of inpatient days as the output measure. However, such an index does not reflect the treatment's true productivity. Shortening the length of stay needed to cure the disease is a good measure of medical-service quality from the patient's perspective. In addition, using average length of stay as an indicator of hospital quality reflects the fact that shortening hospital stays is an important policy target in Japan. In fact, several empirical studies in other countries used length of stay as a measure of hospital efficiency (e.g., Fenn and Davies, 1990; Martin and Smith, 1996). Recently, Cooper et al. (2010) use average length of stay as the measure of hospital efficiency to indicate that the introduction of patient choice and hospital competition in the English NHS in January 2006 has prompted hospitals to become more efficient. Obviously, the quality of inpatient services will decline if reductions in lengths of stay degrade patients' health outcomes. However, recent empirical studies, including Japanese studies, indicate that shortening the length of hospital stays does not detract from treatment outcomes (see Picone et al., 2003; Nawata et al., 2006; Farsi, 2008). Furthermore, the Patient's Behavior Survey (MHLW) indicates that shorter lengths of stay raise patients' satisfaction rates and that those rates have risen in recent years (see Figure 2). Of course, this quality adjustment is minimal, as we do not adjust for the treatment "outcomes" a patient might experience only after leaving the hospital, such as an extended life span or an improvement in quality of life (QOL). However, this measurement has the advantage of being applicable not just to a specific disease or treatment but to hospitals as a whole.

As mentioned, the annual hospital cost of inpatient treatment is 13.2 trillion yen, which accounts for 73.3% of the total hospital cost (18.0 trillion yen) in 2008. It is natural to focus on inpatient care, the dominant factor in overall hospital productivity. We do not use the number of outpatients as an output measure, because we unfortunately do not have a good proxy for the quality of outpatient care. Moreover, our unit of analysis—the medical area—is defined as an area which provides *inpatient* medical services self-sufficiently. We use the ratio of inpatients (the total number of inpatients/ [the total number of inpatients + the total number of outpatients]) as a control variable in order to control the possible bias caused by differences or changes in the composition of inpatients and outpatients.

This study considers measures of capital and labor as inputs. We use the number of beds multiplied by the utilization rate as a proxy for capital input and the number of physicians (full-time equivalent) as labor input. Estimating productivity (especially within the service industry), adjustments of capital utilization and working hours are often difficult by lack of data. This paper achieves these adjustments, however, by using the abovementioned measures. The physician is the most important labor input in the medical services, but we must consider many other kinds of workers, such as nurses, medical machine experts, and office staffs. Unfortunately, data on the full-time equivalent number of these workers are not available. We include the ratio of physicians to the total number of staff members as a control variable.

In a productivity analysis spanning several years, the choice of an appropriate deflator to create real value is critical when one employs the monetary value of output or input (sales, value-added, book value of capital, etc.). However, all of the variables in this paper are physical measurements. Thus, productivity measurements remain unaffected by time-series changes in price and price differentials among regions. This is one of the important advantages of the production function approach, since using monetary measurements is unavoidable when estimating cost functions.

Estimating production function without imposing constant returns to scale assumption makes it easy to get an estimate of the scale elasticity from the coefficients for inputs. However, it is important to note that the measured scale elasticity indicates only medical area level economies of scale, as we are using regional-level data. We would need to estimate hospital-level economies of scale if we wanted information on the possible productivity-enhancing effects of hospital consolidation. Thus, we use the average size of hospitals by region (the number of physicians divided by the number of hospitals in the region) as an additional explanatory variable.

We estimate Cobb-Douglas production functions by pooled OLS and fixed effect (FE) to control unobservable regional characteristics.[5] Regional differences in demographics, food, or endemic diseases may bias healthcare analyses. Fixed effect estimation can control time-invariant regional characteristics.[6]

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[5] We also estimate the translog production function, which is a representative flexible production function, to check the robustness of the results.

[6] We also conducted random-effect (RE) estimations, but the RE models are rejected by the Hausman test for all of the regressions.

As explained earlier, we employ data collected between 1997 and 2008 for prefecture-level analysis and data collected between 1998 and 2007 for the secondary medical area level analysis. Japan's population has aged quickly, and many healthcare policy reforms have occurred during the analysis period. This study uses year dummies to control the effects of those changes.

We express all of the independent variables except year dummies as logarithmic forms in order to enable the estimated coefficients as elasticity. Thus, we can write the equation to be estimated as follows:

$$
\begin{aligned}
\ln (\text{total number of inpatient days/average length of stay})_{it} \\
&= ß_0 + ß_1 \ln (\text{number of beds*utilization rate})_{it} \\
&+ ß_2 \ln (\text{full-time equivalent number of physician})_{it} \\
&+ ß_3 \ln (\text{physician ratio})_{it} + ß_4 \ln (\text{ratio of inpatients})_{it} \\
&+ ß_5 \ln (\text{average size of hospital})_{it} + \Sigma_y ß_y \text{ year dummies} + u_{it}
\end{aligned}
$$

The list of the major variables and their summary statistics are shown in Table 1. The average number of full-time equivalent physicians per hospital is 18.2, but there is a significant variation from 9.2 to 37.3 at the prefecture level. There is more variation at the secondary medical area level, from 4.8 to 113.9 in that case. We confirm that the healthcare supply systems are heterogeneous among regions.

4. Results

Before presenting regression results, we should consider the nationwide aggregate time-series properties of the number of hospitals, the number of physicians, the average size of hospitals, the number of beds, and the average length of stay (see Table 2). The number of hospitals shows a decreasing trend: from 9,442 in 1997 to 8,803 in 2008 (-0.6% on an annual basis). On the other hand, the average size of hospital—the number of full-time equivalent physicians per hospital—is gradually increasing: 17.35 in 1997 to 21.35 in 2008. The total number of beds decreased by 51,000 (-0.3% on an annual basis) between 1997 (when there were 1,663,000) and 2008 (when there were 1,613,000). The average length of hospital stay diminished by 8.7 days between 1997 (when it was 42.5 days) and 2008 (when it was 33.8 days), demonstrating the effectiveness of the policies designed to reduce length of stay. Figure 3 compares output measures both with and without adjustments for the average length of stay—the definition of healthcare quality in this paper. The physical output of Japanese hospitals decreased by -0.5% annually between 1997 and 2008 when not adjusted by the length of stay, but the quality-adjusted output increased at a rate of 1.6% per year, indicating 2.1% annual growth in medical service quality. This figure is both reasonable and comparable to the underestimation of quality change in CPI on medical services in the U.S. (2.3% per year), as mentioned in the introduction. Medical services have attained a sizable quality upgrading even when calculated according to such a simple measure as length of hospital stay.

The regression results are shown in Table 3. The sum of the coefficients for capital and labor—medical area scale elasticity—do not exceed unity at either the prefecture or the medical area level. Thus, we do not observe economies of medical area scale. This result suggests that consolidations in the medical area do not necessarily enhance productivity. On the other hand, the coefficients for the average size of hospitals are positive and highly significant both for the prefecture and the secondary medical area estimations (see Table 3 (1), (3)). The coefficients are between 0.2 (secondary medical area) and 0.3 (prefecture) for OLS estimates. These figures mean that statistically and economically significant economies of scale at the hospital level do exist. Doubling the average size of a hospital correlates to a 15% (secondary medical area) to a 23% (prefecture) higher TFP.[7] However, according to the fixed effect (FE) estimation results, which control unobservable time-invariant regional characteristics, the coefficient for the average size of the hospitals is insignificant for the prefecture level estimation (see Table 3 (2)). Economies of hospital scale are not clear at the tertiary medical area, which provides both ordinary and advanced medical treatments. On the other hand, the fixed effect result also produces a significant positive coefficient for the average size of hospitals at the secondary medical area level, although the size is somewhat smaller than the OLS estimation result (see Table 3 (4)). Doubling the average size of hospital increases the TFP by 12%. The consolidation of regional hospitals appears to enhance the productivity of the healthcare sector at the secondary medical area level, which

[7] The effect of the doubling of hospital size is calculated as 2ß-1, where β is the estimated coefficient for the average hospital size.

provides ordinary inpatient medical services self-sufficiently.

We also estimate the translog production functions in order to check the robustness of the results. The coefficients for inputs are not well measured, due perhaps to multicollinearity, but the coefficients for the average size of hospital are almost identical to those of the Cobb-Douglas production functions (see Table 4). The findings concerning the significant economies of hospital scale prove to be robust against the choice of the functional forms.

The above results are based on the quality-adjusted output measure. Would they be different if we used the quality-unadjusted output measure as a dependent variable—the annual cumulative number of inpatient days? Table 5 presents the regression results by using a simple quality-unadjusted output measure. According to the pooled OLS results, the coefficients for labor input become very small, the coefficients for capital (beds*utilization rate) are close to unity, and the statistical significance level is very high (see Table 4 (1), (3)). The number of beds adjusted by the utilization rate determines the cumulative number of inpatient days almost entirely. This result suggests that the Medical Care Plan System introduced in the 1985 revision of the Medical Care Act and the regulation of the number of beds seems to have effectively controlled the actual number of beds.

The estimation results for prefectures show that the coefficients for the size of hospital are small and produce a significant negative figure (-0.0014) in the pooled OLS and are marginally significant and produce a small positive figure (0.0084) in the fixed effect model (see Table 4 (1), (2)). The effects of doubling the average hospital size on the TFP are -0.1% (OLS) and 0.6% (FE). In the secondary medical area, the coefficient for hospital size is insignificant (OLS) and produces a positive but small figure (FE). All of these results are completely different from the results generated by quality-adjusted output measurements. Economies of hospital scale impact on the TFP mainly through the effects of improvements to medical service quality. An appropriate treatment of the length of stay is a critically important component of the analysis of hospital efficiency.

5. Conclusion

Medical services are becoming increasingly important as Japan deals with its rapidly aging population. This paper estimates the total factor productivity of hospitals by using Japanese regional-level panel data. The study pays special attention to the economies of scale at the medical area and hospital levels.

This paper use quality-adjusted total inpatient days as the hospitals' output measure in assessing policy initiatives designed to control medical costs. We use the length of hospital stay to represent the quality of impatient care. The appropriate treatment of case-mix variability among hospitals has been an important measurement issue in estimating hospital productivity. Using regionally aggregated data is one of the practical ways to control for the case-mix bias. Regional differences in demographics, habit of meals, and endemic diseases often complicate healthcare analyses. We control time-invariant regional characteristics by using panel data sets spanning more than 10 years and employing a fixed effect estimator. Furthermore, this paper employs physical (quantity-based) input and output measures, as an appropriate price deflator to create real value is often difficult to find in a productivity analysis spanning several years. The measured physical productivity is unaffected by time-series changes in price or price differentials among regions.

The analysis in this paper uncovers statistically and economically significant economies of scale at the hospital level. Hospital productivity increases by more than 10% when the average size of hospitals at the secondary medical area level doubles. This effect cannot be confirmed clearly without considering the "quality" of the medical care as proxied by the average length of stay. In other words, hospital-level economies of scale are generated through improvements in the quality of inpatient care. On the other hand, this study finds no medical area level economies of scale. These results suggest that the consolidation of small regional hospitals into larger ones may contribute to the productivity growth of the healthcare sector.

Of course, the quality adjustment in this paper is minimal, because we do not adjust for such "outcomes" of a treatment as may occur after the treatment ends, such as an extension of a life span or an improvement in QOL. In addition, this study does not explicitly consider the amenities of hospitals, the work intensity of physicians, the input of medicines, and the quality of medical equipment. However, the bias caused by the omission of these variables is not serious in comparison with the hospital-level analysis, as this paper uses the prefecture and the secondary medical area as its analytical units.

References

Berndt, Ernst R., David M. Cutler, Richard G. Frank, Zvi Griliches, Joseph P. Newhouse and Jack E. Triplett (2000), “Medical Care Prices and Output,” *Handbook of Health Economics, Vol.1, Part 1*, Ch. 3, pp. 119-180.

Carey, Kathleen (1997), “A Panel Data Design for Estimation of Hospital Cost Functions,” *Review of Economics and Statistics*, Vol. 79, No. 3, pp. 443-453.

Cooper, Zack, Stephen Gibbons, Simon Jones, and Alistair McGuire (2010), “Does Hospital Competition Improve Efficiency? An Analysis of the Recent Market-Based Reforms to the English NHS,” CEP Discussion Paper, No. 988.

Cutler, David M. and Ernst R. Berndt (2001), *Medical Care Output and Productivity*, Chicago: University of Chicago Press.

Farsi, Mehdi (2008), “The Temporal Variation of Cost-Efficiency in Switzerland's Hospitals: An Application of Mixed Models,” *Journal of Productivity Analysis*, Vol. 30, No. 2, pp. 155-168.

Fenn, Paul and Philip Davies (1990), “Variations in Length of Stay: A Conditional Likelihood Approach,” Journal of Health Economics, Vol. 9, No. 2, pp. 223-234.

Gaynor, Martin, Harald Seider, and William B. Vogt (2005), “The Volume–Outcome Effect, Scale Economies, and Learning-by-Doing,” *American Economic Review*, Vol. 95, No. 2, pp. 243-247.

Gobillon, Laurent and Carine Milcent (2010), “Spatial Disparities in Hospital Performances,” CEPR Discussion Paper, No. 7826.

Gordon, Robert J. and Zvi Griliches (1997), “Quality Change and New Products,” *American Economic Review*, Vol. 87, No. 2, pp. 84-88.

Hollingsworth, Bruce (2003), “Non-Parametric and Parametric Applications Measuring Efficiency in Health Care,” *Health Care Management Science*, Vol. 6, No. 4, pp. 203-218.

Hollingsworth, Bruce (2008), “The Measurement of Efficiency and Productivity of Health Care Delivery,” *Health Economics*, Vol. 17, No. 10, pp. 1107-1128.

Ito, Yukiko (2010), “Centrally Clustered Health Care: Why Agglomeration of Health Care Resources is an Effective Strategy” NIRA Research Report, pp. 46-63 (in Japanese).

Keeler, Thodore E. and John S. Ying (1996), “Hospital Costs and Excess Bed Capacity,” *Review of Economics and Statistics*, Vol. 78, No. 3, pp. 470-481.

Lebow, David E. and Jeremy B. Rudd (2003), “Measurement Error in the Consumer Price Index:

Where Do We Stand?" *Journal of Economic Literature*, Vol. 41, No. 1, pp. 159-201.

Li, Tong and Robert Rosenman (2001), "Estimating Hospital Costs with a Generalized Leontief Function," *Health Economics*, Vol. 10, No. 6, pp. 523-538.

Martin, Stephen and Peter Smith (1996), "Explaining Variations in Inpatient Length of Stay in the National Health Service," *Journal of Health Economics*, Vol. 15, No. 3, pp. 279-304.

Morikawa, Masayuki (2009), "Economies of Density and Productivity in Service Industries: An Analysis of Personal-Service Industries Based on Establishment-Level Data," *Review of Economics and Statistics* (forthcoming)

Motohashi, Kazuyuki （2009), "Productivity of Japanese Medical Service: Total Factor Productivity and DEA Analysis of Hospital," ESRI Discussion Paper Series, No. 210 (in Japanese).

Nawata, Kazumitsu, Ayako Nitta, Sonoko Watanabe, and Koichi Kawabuchi (2006), "An Analysis of the Length of Stay and Effectiveness of Treatment for Hip Fracture Patients in Japan: Evaluation of the 2002 Revision of the Medical Service Fee Schedule," *Journal of Health Economics*, Vol. 25, No. 4, pp. 722-739.

Newhouse, Joseph P. (1994), "Frontier Estimation: How Useful a Tool for Health Economics?" *Journal of Health Economics*, Vol. 13, No. 3, pp. 317-322.

Ogawa, Hikaru and Rikizo Kubo (2005), "Technical Efficiency of the Secondary Medical Area," *Health Care and Society*, The Health Care Science Institute, Vol. 15, No. 2, pp. 39-49 (in Japanese).

Picone, Gabriel A., Frank A. Sloan, Shin-Yi Chou, Donald H. Taylor, Jr. (2003), "Does Higher Hospital Cost Imply Higher Quality of Care?" *Review of Economics and Statistics*, Vol. 85, No. 1, pp.51-62.

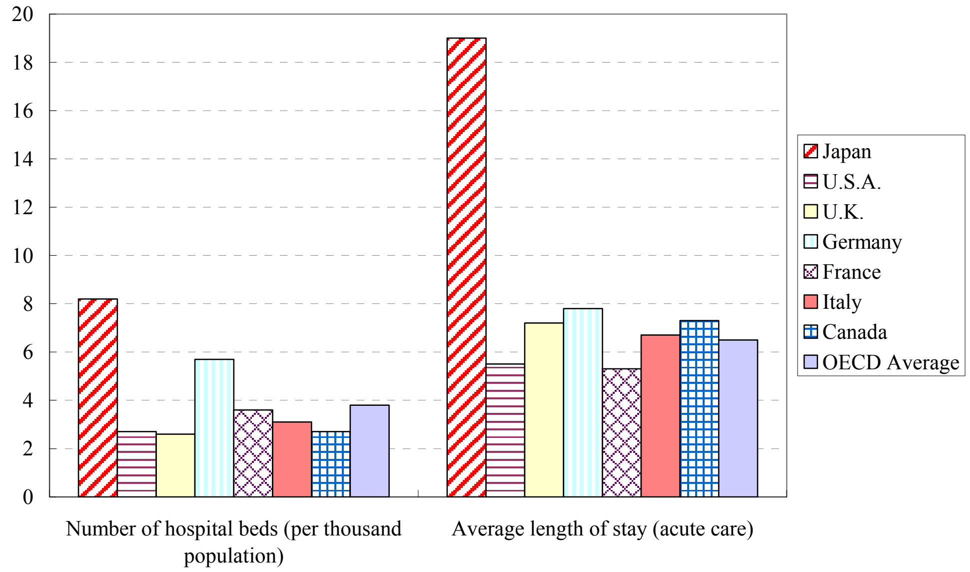
Preyra, Colin and George Pink (2006), "Scale and Scope Efficiencies through Hospital Consolidations," *Journal of Health Economics*, Vol. 25, No. 5, pp. 1049-1068.

Propper, Carol and John Van Reenen (2010), "Can Pay Regulation Kill? Panel Data Evidence on the Effect of Labor Markets on Hospital Performance," *Journal of Political Economy*, Vol. 118, No. 2, pp. 222-273.

Vitaliano, Donald F. (1987), "On the Estimation of Hospital Cost Functions," *Journal of Health Economics*, Vol.6, No.4, pp.305-318.

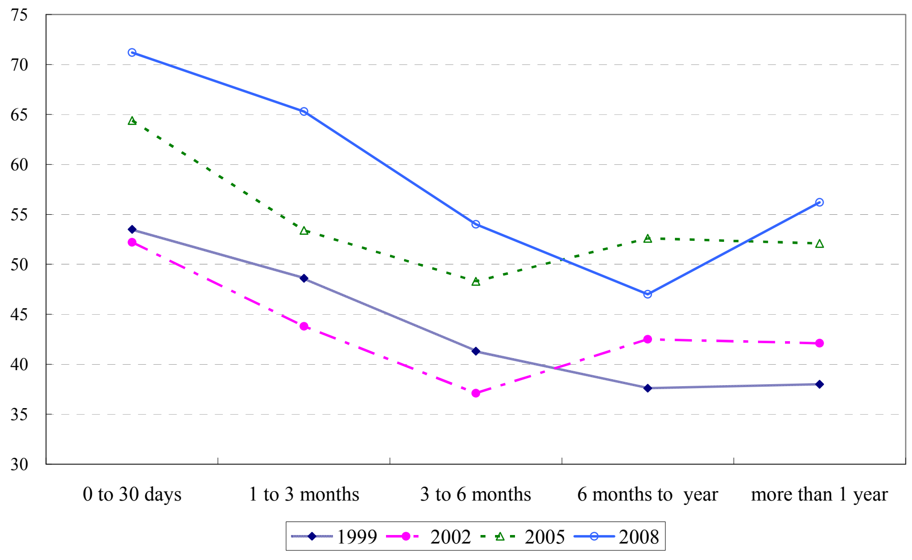
Figures and Tables

Figure 1 The Number of Beds and the Average Length of Hospital Stay (International Comparison, 2007)



(Source) OECD (2010), *Health at a Glance 2009*.

Figure 2 Health Care Satisfaction Index (Diffusion Index) by Length of Stay



(Source) Patient's Behavior Survey (MHLW).

(Note) Health Care Satisfaction Index (Diffusion Index) is calculated by subtracting the share of "unsatisfied" patients (%) from the share of "satisfied" patients (%).

Table 1 Summary Statistics

(1) Prefecture

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
Total number of inpatient days	10,717,510	8,511,685	2,743,433	39,806,720
Total number of outpatient visits	12,934,560	11,700,000	2,726,674	63,956,550
The number of hospitals	194.5	146.5	43	703
Beds-utilization rate	84.4	3.1	76.8	91.4
Number of beds	34,863	27,878	8,681	134,628
Average length of stay	39.6	7.9	26.0	64.8
Number of physicians	3,711	3,844	900	24,030
Number of total staff members	35,357	29,930	7,986	160,399
Number of physicians per hospital	18.2	5.1	9.2	37.3

(2) The Secondary Medical Area

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
Total number of inpatient days	1,331,434	1,495,819	9,490	14,200,000
Total number of outpatient visits	1,577,330	1,782,019	50,370	13,800,000
The number of hospitals	24.8	26.7	1	255
Beds-utilization rate	84.0	6.2	36.1	97.3
Number of beds	4,306	4,792	54	44,687
Average length of stay	43.5	16.8	11.5	129.1
Number of physicians	455	665	6	6,491
Number of total staff members	4,363	5,075	36	45,500
Number of physicians per hospital	15.8	10.4	4.8	113.9

(Source) Ministry of Health, Labour and Welfare, Hospital Report and Survey of Medical Institutions.

Table 2 Trends in Hospital in Japan

	Number of hospitals	Number of physicians	Number of physicians per hospital	Number of beds	Average length of stay
1997	9,442	163,788	17.3	1,663,258	42.5
1998	9,358	164,873	17.6	1,658,156	40.8
1999	9,304	166,617	17.9	1,649,201	39.8
2000	9,272	167,366	18.1	1,645,464	39.1
2001	9,222	169,769	18.4	1,644,723	38.7
2002	9,193	174,261	19.0	1,641,973	37.5
2003	9,139	175,897	19.2	1,636,892	36.4
2004	9,082	177,613	19.6	1,631,338	36.3
2005	9,021	180,022	20.0	1,629,589	35.7
2006	8,961	181,191	20.2	1,628,022	34.7
2007	8,876	183,828	20.7	1,621,663	34.1
2008	8,803	187,948	21.4	1,612,625	33.8

(Source) Ministry of Health, Labour and Welfare, Hospital Report and Survey of Medical Institutions.

Figure 3 Hospital Output Growth with and without Adjustment of the Length of Stay (1997=1)

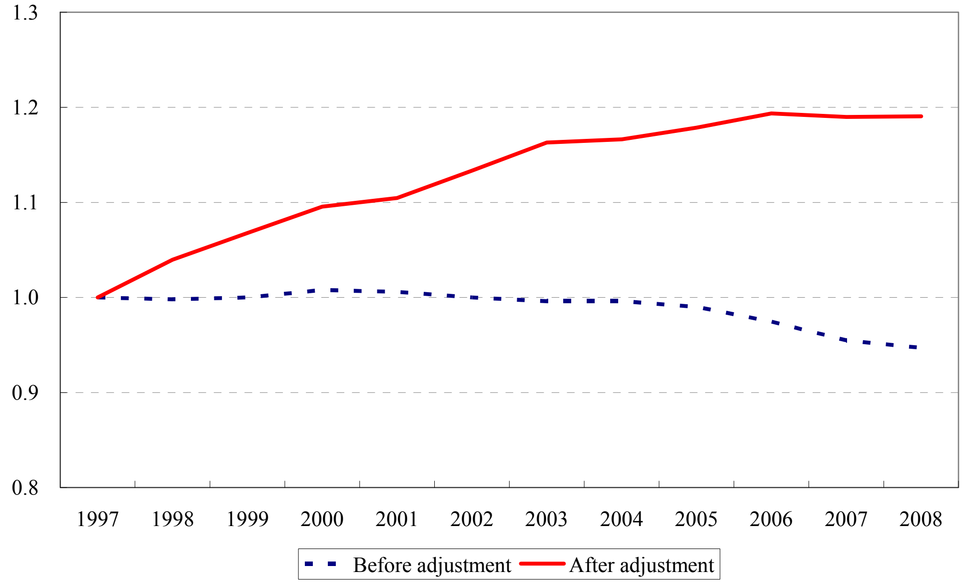


Table 3 Production Function Estimation Results

	Prefecture				Secondary medical-area			
	(1)		(2)		(3)		(4)	
	pooled OLS		FE		pooled OLS		FE	
ln (beds*utilization)	0.1683	**	0.4725	***	0.2505	***	0.2773	***
	(1.98)		(8.27)		(7.01)		(8.99)	
ln (physician)	0.8102	***	0.0505		0.7169	***	0.5281	***
	(9.68)		(0.89)		(20.54)		(18.16)	
ln (physician/total staff)	-1.0429	***	0.0384		-0.6423	***	-0.3406	***
	(-10.79)		(0.73)		(-15.54)		(-12.53)	
ln (inpatient ratio)	-0.7500	***	-0.3655	***	-0.8334	***	-0.4197	***
	(-14.92)		(-7.70)		(-30.88)		(-11.87)	
ln (physician/hospital)	0.2960	***	0.0412		0.2060	***	0.1694	***
	(13.44)		(1.03)		(17.95)		(7.51)	
Constant	0.2880	*	6.7107	***	1.2654	***	3.2532	***
	(1.78)		(16.64)		(12.62)		(15.75)	
Year dummies	yes		yes		yes		yes	
Number of obs.	564		564		2,390		2,390	
Adj. R-squared	0.9880		0.9211		0.9790		0.5270	

(Notes) The average length of stay is adjusted in the calculation of output. t-values are in parentheses.

*significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

Table 4 Estimated Coefficients for the Average Size of Hospitals (Comparisons of Translog and Cobb-Douglas Production Functions)

	Prefecture				Secondary medical-area			
	(1)		(2)		(3)		(4)	
	Translog		Cobb-Douglas		Translog		Cobb-Douglas	
Poled OLS	0.2972	***	0.2960	***	0.2344	***	0.2060	***
	(13.72)		(13.44)		(21.76)		(17.95)	
FE	0.0186		0.0412		0.1222	***	0.1694	***
	(0.47)		(1.03)		(5.44)		(7.51)	

(Notes) The average length of stay is adjusted in the calculation of output. t-values are in parentheses. *significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Table 5 Estimation Results without Adjusting the Length of Stay

	Prefecture				Secondary medical-area			
	(1)		(2)		(3)		(4)	
	pooled OLS		FE		pooled OLS		FE	
ln (beds*utilization)	0.9921	***	0.9766	***	0.9230	***	0.6840	***
	(393.07)		(135.38)		(149.88)		(52.33)	
ln (physician)	0.0078	***	0.0100		0.0751	***	0.2831	***
	(3.13)		(1.39)		(12.48)		(22.97)	
ln (physician/total staff)	-0.0075	***	-0.0142	**	-0.0879	***	-0.2505	***
	(-2.59)		(-2.13)		(-12.34)		(-21.74)	
ln (inpatient ratio)	0.0026	*	0.0128	**	0.0316	***	0.1633	***
	(1.77)		(2.14)		(6.80)		(10.89)	
ln (physician/hospital)	-0.0014	**	0.0084	*	0.0012	*	0.0618	***
	(-2.09)		(1.65)		(0.59)		(6.47)	
Constant	5.9064	***	6.0112	***	5.8964	***	6.1814	***
	(1228.05)		(118.16)		(341.26)		(70.62)	
Year dummies	yes		yes		yes		yes	
Number of obs.	564		564		2,390		2,390	
Adj. R-squared	1.0000		0.9942		0.9994		0.8522	

(Notes) The average length of stay is not adjusted in the calculation of output. t-values are in parentheses. *significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.