No. 823

Cost Analysis of Japanese Municipal Hospitals: Cross-Section Data in1992 Fiscal Year

by

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May 1999

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Abstract

This paper examines whether there exists a range of output where the municipal hospitals in Japan can get positive profits. Data of 934 hospitals are used to estimate the short-run total cost function with two products: inpatient and outpatient care services. We find (i) it is impossible for most of the sample hospitals to get rid of the deficit even if they operate in optimal scales in the short-run, while that seems possible for many in the long-run, (ii) over-investment in the capital equipment in the short-run, (iii) the output ratio affecting differently in the short-run and in the long-run.

JEL Classification Numbers: I10, C51, D21.

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1 Introduction

Recently the hospital sector of municipal firms in Japan has been in financial difficulties. In 1992, the revenue that all municipal hospitals gained by providing health care services was 2646 billion yen which covered about 80 % of the total cost of the same period. This implies that the municipal hospitals can not pay for their costs solely by selling their products.

Except for the fluctuations of demand for health care services which may often be difficult to predict, there may be three major factors that determine the profit of each municipal hospital as a cost minimizer which has to meet an exogenously given demand: the regulated output prices, exogenously given outputs, and the efficiency of hospital administration. As far as the second factor is concerned, we consider in this paper if there is a range of output that attains nonnegative profits.

From the viewpoint of cost analysis on a specific production technique, there seem to be two alternative causes for the negative profit. Not only positive profit is technically impossible for the hospitals in any production scale under the restricted prices of hospital products, but also the hospitals may not make their production at such scales in spite of the existence of the production scale of positive profits. Thus once we obtain the cost function of each hospital, we can see which of the two situations apply.

In the Japanese hospital administration the health care services are basically classified into two groups: inpatient services and outpatient services. The two different services, taken in this paper as the outputs of the hospital, require the hospital to provide different kinds of jobs in different ways. So it can be easily imagined that the ratio of these two outputs as well as the scale of the production influence the hospital cost. Since the outputs are often treated as exogenous variables in each hospital's cost minimization, this output proportion is also exogenous. However, if we can find that the hospital's profitability varies along with the output ratio, we can partly know how the direction of the change in the distribution of the hospital types should be.

It is also often argued whether the level of capital equipments of the hospitals is in excess or falls short from the viewpoint of cost minimization. Capital equipments are usually difficult to adjust quickly and are therefore often treated as fixed inputs in the production of health care services based on the short-run cost analysis. It then becomes of interest to know how much deviation the capital equipments show from the cost minimizing levels in the municipal hospitals in Japan.

To answer the questions posed above, we make the assumption in this paper that each municipal hospital in Japan minimizes its cost in the short-run to estimate its total cost function. Then we try to investigate several characteristics of hospital cost structure.

The remaining part of this paper is as follows. After we present an econometric model to estimate the cost function in Section 2, data used are explained in Section 3. Section 4 reports the results of estimation, with the possibility of nonnegative profit and the effects of output ratio discussed in the short-run and in the long-run.

2 The Model

We assume that each hospital's cost C is generated by

$$C = C_S(Y, W, R, K), \tag{1}$$

where C_S is a short-run total cost function of each hospital, Y is the vector of outputs, W is the vector of prices of variable factors, R and K are the vectors of the prices and the quantities of fixed inputs, respectively. Each hospital faces competitive input markets. Then this expression means that each hospital minimizes its cost given the levels of outputs, the input prices and the levels of fixed inputs with an identical production function. We do not assume that each hospital is in the long-run equilibrium of cost minimization. Instead, we can know if each hospital is in the long-run equilibrium by looking at the partial derivatives of C_S with respect to the fixed inputs K evaluated at each observation. Thus if the following condition holds in the sample, we should assume the long-run cost functions instead of short-run ones:

$$\frac{\partial C_S}{\partial K}(Y, W, R, K) = 0. \tag{2}$$

As noted earlier, we consider that Y consists of two products, the number of inpatients (Y_1) and the number of outpatients (Y_2). They are supposed to be exogenous variables to each hospital as usual, since we assume that the hospitals should meet their demand as much as possible. We assume further that the ratio of Y_1 to Y_2 is exogenous to each hospital.

Now let us specify the functional form of the short-run total cost function C_S. We adopt the translog specification for the short-run total cost function of each hospital mainly because of its usefulness in finding the minimum optimal scale defined later:

$$\begin{aligned} \log C_S(Y,W,K) &= \alpha + \sum_{i=1}^{2} \alpha_i \log Y_i + \alpha_W \log W + \alpha_K \log K \\ &+ \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \beta_{ij} \log Y_i \log Y_j + \frac{1}{2}\beta_{WW} (\log W)^2 \\ &+ \frac{1}{2}\beta_{KK} (\log K)^2 + \sum_{i=1}^{2} \beta_{Wi} \log Y_i \log W \\ &+ \sum_{i=1}^{2} \beta_{Ki} \log Y_i \log K + \beta_{WK} \log W \log K. \end{aligned} \tag{3}$$

where $\beta_{ij} = \beta_{ji}$. Since we want to focus on the output aspects of the cost, other arguments of the cost function are very simplified. W is the variable input price index which is treated as a weighted index of wages of several types of labor inputs. K is also a scalar, representing the hospital's capital equipments as a fixed input. The hospitals are considered to face the same fixed input price within one period of time, and therefore the prices of fixed inputs R are omitted in the specification, due to the data used in estimating the cost function being a cross-section data of a single fiscal year(1992).

A labor cost share function is derived by Shephard lemma:

$$S_W = \frac{\partial \log C_S}{\partial \log W} = \alpha_W + \sum_{i=1}^{2} \beta_{Wi} \log Y_i + \beta_{WW} \log W + \beta_{WK} \log K. \tag{4}$$

The translog total cost function and the labor cost share function are estimated by the Seemingly Unrelated Regression method.

The cost function in (3) should satisfy the following properties

$$\epsilon_i = \frac{\partial \log C_S}{\partial \log Y_i} > 0, \quad i = 1, 2. \tag{5}$$

$$0 < \frac{\partial \log C_S}{\partial \log W} < 1. \tag{6}$$

$$\frac{\partial^2 C_S}{\partial W^2} < 0. \tag{7}$$

3 Data

All data about the municipal hospitals in Japan was collected from *The Yearbook of Public Firms* 1992 (*Kouei Kigyou Nenkan,* in Japanese) by Institute of Local Finance (*Chihou Zaimu Kyoukai,* in Japanese). It reports data for each of the 990 municipal hospital in Japan. Several hospitals were excluded because they did not have the complete set of necessary items or because they had zero values for specific items that precluded us from taking logarithms. The final sample size is 934.

We used the total cost which is found in the above data source as C_S. This consists of all costs of each hospital summed up within the period. Y_1 is the number of the inpatients per day and Y_2 is the number of outpatients per day. K represents the quantity of capital equipments, defined as the book value of buildings and equipments.

There are five categories of employees reported (administrative worker, physician, registered nurse, non-registered nurse, others). W is then obtained as follows:

$$W = \prod_{h=1}^{5} w_h^{s_h}, \quad s_h = \frac{w_h L_h}{\sum_{h=1}^{5} w_h L_h}, \; h = 1, \ldots, 5. \tag{8}$$

where L_h is the number of workers of the h-th category, w_h is the average sum of the basic wage and allowances of the category. We did not contain non-labor inputs, such as drugs, since they are not available, though the way they are used is an interesting problem in Japan. The definition of the variables stated above and their descriptive statistics are shown in Table 1. We divided them by their own sample mean before we take the logarithms.

In the data source the hospitals are classified according to four categories (general, psychiatric, tuberculous, infectious). 94.2 % of 990 hospitals are classified as the general. Since we are chiefly interested in the effect of the scale of production on the cost, we did not distinguish the categories of hospitals.

Finally, the output prices are defined as follows. For inpatient services(Y_1), its price P_1 is the revenue from providing inpatient services divided by Y_1. Similarly, we obtained P_2 for the price of outpatient services.

4 Empirical Results for Japanese Municipal Hospitals

The result of parameter estimation of (3) together with (4), using the cross-section data described in the former section, is presented in Table 2.

The three properties [(5), (6) and (7)] that a total cost function must have were satisfied in all observations (Table 3). The estimated cost function therefore displays theoretically consistent properties. The table also shows that $\partial \log C_S / \partial \log K$ does not equal to zero, which implies the plausibility of adopting the short-run costs instead of the long-run. It is discussed based on the induced long-run cost function later.

The two outputs are treated as exogenous by assumption. Under these assumptions, when we want to know about possibilities of positive profit production as well as the scale economies, it seems convenient to apply the concept of the Ray Average Cost in the short-run $A_S(t)$ which is defined as follows

$$A_S(t) = C_S(tY, W, K)/t, \quad t > 0. \tag{9}$$

where (Y, W, K) are held constant. The economy of scale in the short-run exists if the following index exceeds one:

$$SN_S = \left(1 + \frac{\partial \log A_S(t)}{\partial \log t}\right)^{-1}, \text{ where } t = 1. \tag{10}$$

Table 4 shows economies of scale seem to exist in the hospitals of relatively small size, *i.e.*, hospitals with less than 300 beds.

Let us define the minimum optimal scale in the case of joint production as $Y^* = t_S^* Y$ where

$$t_S^* = \{t | \min_t A_S(t)\}. \tag{11}$$

When the Ray Average Cost curve is U-shaped, t_S^* is characterized by $\partial \log A_S(t)/\partial t = 0$. In order to calculate the minimum optimal scale defined above, let us first look at the shape of the Ray Average Cost. The second derivative of $\log A_S(t)$ for the translog specification (3) is

$$\frac{\partial^2 \log A_S(t)}{\partial \log t^2} = \sum_{i=1}^{2} \sum_{j=1}^{2} \beta_{ij}, \tag{12}$$

and its estimate 0.214(0.040, standard deviaton in parentheses) is significantly positive. This means that the Ray Average Cost Curve has a unique minimum. Hence the minimum optimal scale t_S^* is obtained by solving $A_S'(t_S^*) = 0$.

In the sample mean, $t_S^* = \exp(\sum_{i=1}^{2} \alpha_i - 1)/(\sum_{i=1}^{2} \sum_{j=1}^{2} \beta_{ij})$=0.868(0.081), and this implies the minimum optimal scale is the scale that is achieved by a reduction of 13.2 % from the present scale of production. If all(934) of the hospitals produce at such optimal scale, then the deficit per each hospital becomes .38 billion yen.

Let us look at the profit by the production at such minimum optimal scale. The profit is calculated as

$$\pi_S^* = t_S^* \left(\sum_{i=1}^{2} P_i Y_i \right) - C_S(t_S^* Y, W, K). \tag{13}$$

As a result, 864 hospitals(92.5 %) have a negative value for π_S^*(Table 5). We classify the sample hospitals into two groups: group A for the hospitals whose profit at the minimum optimal scale is negative, and group B for others. For hospitals in group A it can be said that increases in output price or changes in fixed inputs are necessary in order to have positive profit, as long as the efficiency of hospital administration is held unchanged.

4.1 Hospital Cost and the Inpatient-Outpatient Ratio

In this paper the relative ratio of outputs and the output prices are treated as exogenous variables in the cost minimizing behavior of each hospital. The exogeniety assumption on the ratio of the number of inpatients to that of outpatients makes the concept of the Ray Average Cost more useful. But due to the ratio varying over the hospitals in the sample, we investigate in this section the relation between the inpatient-outpatient ratio and the hospital cost. Hereafter the output ratio is denoted as θ, which is defined as the ratio of the number of the inpatients per day to that of outpatients per day, *i.e.*, $\theta = Y_1/Y_2$.

The sample mean and the sample standard deviation of the number of beds and the output ratio(θ), which are treated as exogenous in estimating the short-run total cost function of the hospitals, are presented in Table 5 for the two groups. There seems to be greater θ for hospitals in group B, while no remarkable difference in the number of the beds is found between the two groups.

To capture the effect of higher θ on the hospital cost, we totally differentiate the short-run total cost function with respect to Y_1 and Y_2, holding W, K constant. Then we obtain

$$d \log C_S = \sum_{i=1}^{2} \epsilon_i d \log Y_i, \tag{14}$$

where $\epsilon_i (i = 1, 2)$ is the short-run total cost elasticity in terms of the i-th output. Suppose the outputs vary so that they keep the revenue of the hospital unchanged. Then using $P_1 Y_1 d \log Y_1 + P_2 Y_2 d \log Y_2 = 0$, the above equation becomes

$$\frac{d \log C_S}{d \log Y_1} = \left(\epsilon_1 - \frac{P_1 Y_1}{P_2 Y_2} \epsilon_2 \right). \tag{15}$$

This is equivalent to

$$\eta \equiv \frac{d \log C_S}{d \log Y_1} = \frac{Y_1}{Y_2} \epsilon_2 \left(\frac{MC_1}{MC_2} - \frac{P_1}{P_2} \right). \tag{16}$$

Equation (16) shows that the essential factor that determines the sign of η is the difference between the ratio of the marginal costs and the output prices. The average revenues per patients per day are 23,495 yen for inpatients and 7,959 yen for outpatients($P_1/P_2 = 2.952$). We can easily evaluate the term inside the parentheses in equation(15) at the sample mean with the translog cost functions, and it is equal to $\alpha - (P_1/P_2)\alpha_2 = -6.408(0.088) < 0$(the values of η are presented in Table 6 for several intervals of θ). This means that at the sample mean, as long as the revenues are constant, lower total cost for hospitals is accompanied by higher θ, resulting in higher profit and higher possibility to be classified in group B. Table 6 shows decreases in η as θ increases. η is negative for hospitals whose θ is greater than 0.2(93 % of all the hospitals in the sample). For hospitals whose θ exceeds 0.8, the cost decreases elastically with further increase in θ. This implies that the profitability of inpatients is higher relative to that of outpatients in the hospital administration in the short-run for most of the hospitals.

4.2 The Long-Run Total Cost Function

The value of $\partial \log C_S / \partial \log K$ in Table 3 does not seem close to zero. If we evaluate it at the sample mean, it equals to α_K which is significantly positive. It follows that the hospitals do not achieve the long-run cost minimization and thus it is plausible to apply the short-run cost function to the sample rather than the long-run cost function. From the cost minimization viewpoint, each hospital has too many capital equipments in the short-run. In this section we investigate the effects of the adjusting fixed inputs to the long-run full equilibrium on the cost of the hospital.

The long-run equilibrium level of input of the fixed factor K is characterized by

$$\frac{\partial \log C_S}{\partial \log K} = \alpha_K + \sum_{i=1}^{2} \beta_{Ki} \log Y_i + \beta_{WK} \log W + \beta_{KK} \log K = 0. \tag{17}$$

Let the solution of this equation be K^*. Then we obtain

$$\log K^* = -\frac{1}{\beta_{KK}} \left(\alpha_K + \sum_{i=1}^{2} \beta_{Ki} \log Y_i + \beta_{WK} \log W \right) \tag{18}$$

The long-run total cost function $C_L(Y, W)$ is obtained by substituting (18) into the short-run total cost function (3). The Ray Average Cost $A_L(t)$ and the index of scale economy SN_L in the long-run are also defined based on $C_L(Y, W)$ simi-larily as in the short-run. The values of SN_L are given in Table 7 for several bed sizes. SN_L evaluated at the sample mean is equal to $1/ \sum_i^2 (\alpha_i - \alpha_K \beta_{Ki} / \beta_{KK})$ $= 0.848(0.019)$, which shows smaller scale economy compared to the short-run.

The second derivative of $\log A_L(t)$ for the translog specificaton (3) is

$$\sum_{i=1}^{2} \sum_{j=1}^{2} (\beta_{ij} - \beta_{Ki} \beta_{Kj} / \beta_{KK}) \, . \tag{19}$$

This value is 0.092 (0.018). Thus the Ray Average Curve is U-shaped in the long-run as well as in the short-run. So the minimum optimal scale in the long-run, t_L^*, is obtained uniquely by solving $\partial \log A_L(t) / \partial \log t = 0$, and the profit of each hospital at such scale can be calculated.

As a result of this calculation, 343 hospitals(36.7 %) have negative value for the profit (hospitals classified in group A in the long-run). Table 8 gives the result together with the number of the beds and the output ratio θ. The table shows higher θ in group A than in group B, which is in contrast with the result in the short-run. The average number of beds is greater in group B. This can be explained in part by the fact that the percentage of the municipal hospitals in Japan that face higher output prices increases as the number of beds expands. Therefore the output ratio θ is one of the important factors that determine the hospitals' profits.

Now we try to investigate what will happen to the long-run hospital profit when θ varies. The elasticity of the long-run total cost with respect to the inpatients when θ varies, keeping the hospital's revenue unchanged, is

$$\eta_L \equiv \frac{d \log C_L}{d \log Y_1} = \left(\frac{\partial \log C_L}{\partial \log Y_1} - \frac{P_1 Y_1}{P_2 Y_2} \frac{\partial \log C_L}{\partial \log Y_2} \right). \tag{20}$$

Table 9 shows the values of η_L evaluated at the minimum optimal scale in the long-run for several intervals of θ. We found that $0 < \eta_L < 1$ for all hospitals. The table indicates smooth increase in η_L as θ increases. Especially, contrary to the short-run case where we could see η falling down to negative value for high θ, no decreasing tendency is found in η_L. This implies that the ratio of the marginal costs exceeds the output price ratio for all hospitals in the sample and the difference grows as the hospitals have more inpatients in place of outpatients.Therefore the hospitals with lower θ have higher possibility to be classified in group B. To accept more outpatients instead of inpatients which may require more capital equipment would improve the profit of the hospitals under the current output price vector in the long-run.

5 Conclusion

This paper has addressed the following basic question: Do the cost of each hospital in Japan exceeds the revenue even at the optimal scale of production? The estimation results of the total cost function suggest that most of the municipal hospitals in the short-run can not achieve nonnegative profit even at the optimal scale of production under the current price settings if the administrative efficiency of the hopital does not change, though they can reduce the deficit by changing their production toward such optimal scale. The prescriptions to decrease the municipal hospitals' deficit are, however, not limited to raise the output prices, since it has been ignored how efficiently the hospital produce. The assumption that any hospital produces health care services in a equally efficient manner sometimes may be fragile and the investigation of the efficiency of hospital administration remains important, although difficult.

Moreover, the capital equipments of the municipal hospitals in Japan seem to exceed the long-run equilbrium level, as often reported in other papers (e.g., Vita, 1990). In fact, it should be noted that the inpatient-outpatient ratio changes the hospitals' profit in opposite directions: positive effect in the short-run and negative in the long-run. As a consequence, the hospitals' capital equipments are often expensive and, once the hospitals decide to supply inpatient care services which need such equipments, they have to reduce the idling equipments in order to reduce the deficits. This happens although they are faced with uncertainty in the types and severeness of the patients' disease, or even the number of the patients itself, before setting such equipments.

Acknowledgements

The author acknowledges Professor Makoto Ohta and André Varella Mollick for valuable comments.

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Table 1. Descriptive Statistics

Variable		Mean	Standard Deviation	Min	Max
C_S	Total cost(million yen)	3388.888	3325.151	118.4	26133.8
W	Wage rate(thousand yen/month)	599.471	74.936	400.6	1064.7
K	Capital stock(Million yen)	2536.580	3391.219	36.4	79911.0
Y_1	Number of inpatients/day	193.369	165.543	2.0	1102.0
Y_2	Number of outpatients/day	467.185	389.152	8.0	2559.0

Table 2. **Parameter Estimates of the Translog Cost Function (3)**

Parameter	Estimate	t-statistic
α	14.9871	1378.93
α_1	.5623	23.0683
α_2	.4076	17.4658
α_W	.3960	172.3600
α_K	.1610	12.8378
β_{11}	.1716	5.1041
β_{12}	−.0342	−1.6027
β_{W1}	.0660	17.2239
β_{K1}	−.0483	−2.1759
β_{22}	.1104	4.1723
β_{W2}	−.0578	−16.2958
β_{K2}	−.0458	−2.9646
β_{WW}	.0414	2.4752
β_{WK}	−.0207	−7.1599
β_{KK}	.0726	3.6094
R^2 of eq.(3)	.9541	
Sample size	934	

Table 3. Short-Run Elasticities of Cost

	Mean	Min	Max
$\partial \log C_S / \partial \log Y_1$	.5397	.2109	.8105
$\partial \log C_S / \partial \log Y_2$	.4146	.0349	.5403
$\partial \log C_S / \partial \log W$	.4046	.3092	.5998
$\partial \log C_S / \partial \log K$	.1455	−.0283	.3394
$\frac{W^2}{C_S} \frac{\partial^2 C_S}{\partial W^2}$	−.2040	−.2086	−.1770

Table 4. Economies of Scale in the Short-Run

Number of Beds	Number of Hospitals	SN_S	Mean Number of Beds
20 – 99	262	1.199	61.176
100 – 199	203	1.073	138.754
200 – 299	166	1.022	237.127
300 – 399	122	.996	335.844
400 – 499	80	.943	437.088
over 500	101	.939	633.980

Table 5. Number of Beds and Inpatients-Outpatients Ratio of Group A and B in the Short-Run

	Number of Hospitals	Number of Beds	Inpatients/Outpatients Ratio(θ)
Group A	864	239.902(191.902)	.547(.808)
Group B	70	232.214(134.424)	.726(1.454)

Standard deviation in Parentheses.

Table 6. Mean values of θ and η Under Constant Total Revenue in the Short-Run

θ	η	Number of Hospitals
up to .2	.1219	65
.2 – .4	−.1301	514
.4 – .6	−.4082	230
.6 – .8	−.9578	53
over .8	−2.5422	72

Table 7. **Long-Run Elasticities of Cost**

Number of Beds	SN_L
20 – 99	.964
100 – 199	.895
200 – 299	.853
300 – 399	.831
400 – 499	.809
over 500	.791

Table 8. **Number of Beds and Inpatients/Outpatients Ratio of Group A and B in the Long-Run**

	Number of Hospitals	Number of Beds	Inpatients/Outpatients Ratio(θ)
Group A	591	134.895(118.939)	.714(1.117)
Group B	343	300.514(193.838)	.472(.678)

Standard deviation in Parentheses.

Table 9. Mean values of θ and η_L Under Constant Total Revenue in the Long-Run

θ	η
up to .2	.4117
.2 – .4	.4576
.4 – .6	.4864
.6 – .8	.5109
over .8	.5943