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Cost Behaviors and Cost Structure of Public Hospitals in India: Analysis from the Perspective of Congestion Costs

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Abstract

The goal of this study is to understand better the relationship between hospital bed occupancy rate and cost rigidity as a proxy for the degree of hospital bed congestion, as well as the relationship between the risk of changes in hospital bed occupancy rate and congestion cost, targeting public hospitals. As public hospitals for analysis, we selected hospital projects from the Public Enterprises Survey Reports published by the Department of Public Enterprises, Ministry of Finance, and obtained unbalanced panel data consisting of 1,505 hospitals and 15 years, totaling 12,595 hospitals and years. The analysis revealed that the risk of changes in the bed occupancy rate increases the degree of cost rigidity and leads to a decrease in the variable cost ratio; furthermore, an increase in the bed occupancy rate decreases the degree of cost rigidity and leads to an increase in the variable cost ratio. These findings suggest that although public hospitals are taking managerial actions to avoid congestion costs, congestion costs resulting from higher bed occupancy rates have not been eliminated. The regression analysis results show that even if congestion costs arise as the occupancy rate increases, they are covered by the increase in revenue associated with the increase in the occupancy rate.

Keywords: Congestion Cost, Bed Occupancy Rate, Cost Structure, Unused Capacity, Cost Behaviors

JEL Classification Code: D24, D61, G18, M40, M41

1. Introduction

In recent years, local public businesses involved in the hospital business (hence referred to as "public hospitals") have faced significant environmental changes. According to the Ministry of Health and Family Welfare's "New Guidelines for Public Hospitals," many public hospitals are in an extremely difficult situation to maintain their medical care delivery systems due to deteriorating management conditions and a shortage of doctors, and the management

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of these hospitals has been attracting social attention, with calls for strengthening management capabilities to ensure sustainable management.

From the perspective of empirical cost behavior research, we study the cost structure and cost fluctuations of public hospitals in such an environment. Empirical cost behavior studies are a type of research that examines cost structures, patterns of variation, and their drivers using archival data (e.g., Anderson et al., 2003; Banker & Byzalov, 2014; Banker et al., 2014a, 2014b; Dungtripop & Srisuwan, 2021; Vu et al., 2020). The research in this domain has improved our understanding of the mechanisms that cause cost incidence. The cost structure and cost fluctuations of public hospitals are expected to be clarified by the analysis of public hospitals, as well as provide practical implications for public hospital management.

The specific objectives of the study are to clarify, for public hospitals, 1) the relationship between the uncertainty of medical demand faced by hospitals and their cost structure, and 2) the relationship between the "congestion" that occurs under conditions of high capacity utilization and cost fluctuations. In the case of a hospital, capacity is defined by management resources such as medical staff (doctors and nurses) and hospital beds. The key concept in this study is the "cost of congestion," for which evidence was presented by Banker et al. (2014b). Congestion cost refers to the large cost or damage caused by a small problem or failure in one part of the system that affects the whole system when capacity utilization is high.

In this study, we selected hospital projects from the Public Enterprises Survey Reports published by the Department of Public Enterprises, Ministry of Finance, and created unbalanced panel data consisting of 1,505 hospitals and 15 years, for a total of 12,595 observation years, and analyzed the data to clarify the actual situation of congestion costs. The number of inpatients, which is disclosed information, was used as an indicator of the uncertainty of demand for medical care at each hospital level. In addition, we used the hospital bed occupancy rate, which is also disclosed information, as a proxy variable for the degree of congestion of hospital beds. These manipulations enable us to verify the cost structure of public hospitals based on concrete data such as the number of inpatients and the occupancy rate of hospital beds and provide basic data on the management of public hospitals as well as practical implications. In addition, the results of this study have academic value in the sense that the congestion cost was directly observed.

The analysis revealed that uncertainty in health care demand leads to the selection of a rigid cost structure and that congestion that occurs in situations with high occupancy rates leads to large cost fluctuations. These findings suggest that although public hospitals are taking managerial actions to avoid congestion costs, the congestion costs associated with high occupancy rates have not been eliminated.

The structure of this paper is as follows. First, in the next section, we review empirical studies on cost behavior. Section 3 presents the research question and analysis methodology of this paper. Section 4 provides an overview of the sample to be analyzed. In Section 5, we present the results of our analysis. Finally, in Section 6, we conclude by identifying the academic contributions and implications of this study for hospital management practice, as well as pointing out the limitations and remaining research questions of this study.

2. Literature Review

2.1. Cost-Behavior

In recent years, empirical cost-behavior studies using archival data have been actively conducted (Banker & Byzalov, 2014; Tu & Giang, 2018). One of the pioneering studies was Anderson et al. (2003). When the rate of increase in costs recorded when revenues rise is compared to the speed of the drop in prices observed when revenues fall, the latter is determined to be smaller in this paper. Because the cost does not fluctuate as much when income declines as it does when revenue increases, this phenomenon is known as "stickiness of cost." The discovery of downward cost rigidity was a significant early cost rigidity research result.

First, the rigidity of costs can be tested by estimating equation (1) below (Banker, Byzalov, et al., 2014b).

$$\log\left(\frac{\text{Cost}_{i,t}}{\text{Cost}_{i,t-1}}\right) = \beta_0 + \beta_1 \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) \tag{1}$$

where $\text{Cost}_{i,t}$ represents the cost of firm i in period t and $\text{Revenue}_{i,t}$ represents the revenue of firm i in period t. Also, log denotes the logarithmic transformation with the natural logarithm as the base.

The estimated β_1 represents the degree to which costs fluctuate in response to changes in revenue, or "cost rigidity." Specifically, this β_1 indicates the so-called elasticity, which means the marginal rate of change in cost for a 1% change in revenue, and is interpreted as the variable cost rate in the context of management accounting and cost accounting. Therefore, β_1 usually takes the value between 0 and 1. And the closer β_1 is to 0 (1), the smaller (larger) the variable cost ratio and the larger (smaller) the fixed cost ratio, which means that "the degree of cost rigidity is high (low)" or "the degree of cost rigidity is strong (weak)."

Second, the downward cost rigidity mentioned earlier is one of the factors that affect the degree of cost rigidity. Therefore, the downward rigidity of costs is tested by estimating the following equation (2), which incorporates a dummy variable ($SDD_{i,t}$) into equation (1) that takes the value of 1 when revenues decrease.

$$\log\left(\frac{\text{Cost}_{i,t}}{\text{Cost}_{i,t-1}}\right) = \beta_0 + \beta_1 \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) + \beta_2 \cdot \text{SDD}_{i,t} \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) \quad (2)$$

Here, if costs are downwardly rigid when revenues decline, then β_2 should be estimated to be negative. Anderson et al. (2003), using data for U.S. firms, showed that β_2 is estimated to be negative, as expected. As an extension of these studies, we can find "anti-downward cost rigidity" associated with two consecutive periods of declining revenue (Banker et al., 2014a) and detect differences in the impact of the degree of revenue increase or decrease on the degree of downward cost rigidity (Ciftci & Zoubi, 2019) and other studies. In any case, this series of studies use a dummy variable ($SDD_{i,t}$ in equation (2)) that identifies the decline in revenue compared to the previous year. Therefore, it can be said that cost rigidity was discussed concerning short-term revenue fluctuations in the early studies.

In recent years, evidence has begun to accumulate that short-term earnings fluctuation and the demand uncertainty that firms face in the long run affect their choice of the cost structure. Banker et al. (2014b), using the standard deviation of earnings as a proxy for demand uncertainty, showed that the degree of cost rigidity increases as demand uncertainty increases, i.e., the variable cost ratio decreases.

According to conventional wisdom, the more uncertain demand becomes, the more firms will use casual employment and leasing contracts to reduce fixed costs while increasing the proportion of variable costs (Balakrishnan et al., 2008; Horngren et al., 2012). However, the findings of Banker et al. (2014b) were contrary to this common belief and were accepted by the academic community with great impact.

Banker et al. (2014b) applied queueing theory, which is mainly used in operations research, pointed out that when capacity utilization increases close to the limit, congestion causes additional costs, i.e., congestion costs. According to their explanation, the higher the uncertainty of demand, the higher the probability that capacity utilization will be extremely high, and the higher the probability that congestion costs will be incurred due to congestion. Therefore, firms prepare sufficient capacity in advance to avoid the congestion costs that arise under high capacity utilization. This implies that a cost structure consisting of small variable costs and high fixed costs, i.e., a rigid cost structure, is chosen. The analytical model they used to verify this is shown in simplified form in equation (3) below.

$$\log\left(\frac{\text{Cost}_{i,t}}{\text{Cost}_{i,t-1}}\right) = \beta_0 + \beta_1 \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) + \beta_2 \cdot \text{Uncert}_i \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) \quad (3)$$

Here, Uncert_i represents the uncertainty of demand faced by firm i, and the standard deviation of the logarithmic difference of earnings over the sample period of firm i is employed as the proxy variable. In other words, the demand uncertainty faced by firm i is assumed to be constant throughout the period under analysis, and the long-run impact of demand uncertainty on the cost structure is the subject of analysis. This is in contrast to the discussion of downward cost rigidity, which focused on cost changes associated with short-term increases and decreases in profits.

2.2. Cost Behavioral Research and Congestion Costs

Congestion cost was first mentioned in cost control research by Banker et al. (1988), who defined it as an increase in accounting cost or opportunity loss induced by product congestion on the manufacturing line. Delays in the front-end process of a production line, for example, propagate to the back-end process, resulting in higher accounting expenses in the form of labor cost and manufacturing overhead cost inefficiencies. Furthermore, if quality flaws are not detected quickly enough while the production line's utilization rate is high, not only will internal and external failure costs, which are a sort of quality cost, be incurred, but commercial possibilities may also be lost due to the loss of reputation and brand power.

Traditionally, the closer the capacity utilization rate is to 100%, the more economical the organization is in terms of economies of scale. However, the existence of congestion costs negates such a notion. As capacity utilization increases and approaches 100 percent, congestion arises from small problems or failures in parts of the business process, and the congestion costs associated with this increase the likelihood of a rapid decline in profits. As seen in road congestion, congestion reduces the inherent processing capacity of the capacity. As a result, if the same amount of processing is attempted in a congested state as in a non-congested state, there will be a temporary shortage of capacity, and additional capacity will need to be acquired.

The acquisition of additional capacity inevitably entails the incurrence of additional costs. If congestion occurs during the increase in capacity utilization and additional costs, i.e., congestion costs, are incurred. As a result, the incremental revenue from the increase in capacity utilization will be offset by the congestion costs. As a result, the incremental profit from the increase in capacity utilization will be smaller. Therefore, understanding congestion costs has important implications for management decision-making.

A way to avoid congestion and the congestion costs that come with it is to secure sufficient capacity in advance. In cost theory, the capacity cost for securing capacity is considered to be a fixed cost. Therefore, the decision to secure sufficient capacity in advance implies the selection of a rigid cost structure in which most of the costs are fixed costs. Banker et al. (2014b) showed that in situations where capacity utilization can be extremely high due to high demand volatility risk, firms choose a cost structure consisting of a small variable cost rate and large fixed costs to avoid congestion costs associated with congestion. This finding implies that firms choose a rigid cost structure to avoid congestion.

The concept of congestion cost, which was developed for manufacturing industries, was applied to the hospital context by Balakrishnan and Soderstrom (2000). Specifically, they examined whether the probability of electing a cesarean section in obstetrics and gynecology was affected by crowding. They chose to study obstetrics and gynecology because delivery is a randomly occurring phenomenon. Random deliveries are a major factor in the occurrence of congestion in obstetrics and gynecology because delays in admitting women in labor are unacceptable. We also focused on a cesarean section because, while cesarean section reduces congestion in obstetrics and gynecology, it is a more costly procedure than natural childbirth. This cost can be interpreted as a form of congestion cost, in the sense that it is additionally incurred during congestion.

Balakrishnan and Soderstrom (2000) examined the degree of crowding in the delivery waiting room using data from 225,473 inpatients at 30 hospitals in Washington State. They found that as crowding increased, cesarean section was more likely to be chosen, especially among patients at high risk of delivery. This is true in the narrow context of obstetrics and gynecology in the United States, but it's unclear whether it extends to Indian institutions, which have different healthcare systems and societal contexts. Their study's contribution, however, is not limited to elucidating the factors that influence the decision to perform a cesarean section. Rather, the contribution of their study is to show that the choice of medical treatment is affected by the degree of congestion in the hospital capacity. However, this study has some limitations: 1) the results are biased toward specific departments, 2) the ratio of congestion costs to total costs is unknown, and 3) congestion costs were not directly identified.

In a more general sense, then, what was the congestion in hospitals that Balakrishnan and Soderstrom (2000) envisioned? They state that the "most important resource constraint" in hospitals is the number of beds (p. 98), and believe that congestion arises from random fluctuations in the number of patients in situations of high bed occupancy. The problem is that in congested situations, the waiting time for each procedure increases, which reduces the efficiency of the entire procedure process.

For example, if congestion arises from the admission of urgent patients in a situation of high bed occupancy, bed control involving the movement of existing inpatients, such as "pile-ups," may be necessary. The efficiency of the entire treatment process is reduced when a portion of a hospital's capacity is devoted to such activities. Low bed occupancy, on the other hand, does not result in a reduction of treatment efficiency across the board. This is because there are enough surplus beds to accommodate urgent patients. Excess capacity, in other words, absorbs additional demand and prevents congestion from occurring.

When congestion occurs in high bed occupancy and the efficiency of the entire procedure process decreases, the hospital suffers a temporary capacity shortage. In this case, the hospital has to compensate for the capacity shortage to maintain the health care delivery system. For example, hospitals can compensate for this lack of capacity by temporarily increasing overtime or temporary staff to meet changing medical demands. However, such a response imposes additional labor costs on the hospital. There may also be additional material costs associated with the selection of more invasive treatments to alleviate congestion and restore efficiency to the overall treatment process (Balakrishnan & Soderstrom, 2000). These costs are also congestion costs that occur only in situations of congestion. In any case, congestion costs will be included in the variable costs that vary more marginally with changes in a unit of medical revenue in congested than in uncongested situations. In other words, the variable cost ratio increases by the magnitude of the congestion cost in a crowded situation compared to a non-congested situation.

3. Research Design and Sample

3.1. Research Design

Based on empirical cost behavior studies, this study clarifies the cost structure and cost fluctuations of public hospitals from the perspective of congestion costs. The academic contributions and practical implications of this are as follows.

First, as a contribution to academia, this study provides empirical evidence for the existence of congestion costs. It is important to note that many of the studies that rely on Banker et al. (2014b) have conducted their analyses assuming the existence of congestion costs. These studies have not directly identified congestion costs, but have only predicted and tested behaviors to avoid congestion costs.

In addition, it is difficult to measure the capacity utilization rate using a common index when a wide variety of for-profit companies are subject to analysis. However, public hospitals disclose their bed occupancy rates, and the calculation method is common among them. As described below, in this study, the occupancy rate is used as a proxy variable for the degree of crowding of hospital beds. This makes it possible to examine the relationship between congestion and cost variation. This paper has an academic contribution as evidence of direct observation of this relationship.

As a contribution to the practical aspects of hospital management, this study provides basic information for discussing the management of public hospitals. Public hospitals may be somewhat tolerant of higher bed occupancy rates due to increased demand for medical care and the congestion costs that may result from this situation. However, the congestion cost may also be a cause of profit pressure. Therefore, elucidating the relationship between the uncertainty of demand for medical care and the cost structure and the extent to which the congestion costs that arise under conditions of high occupancy rates affect cost fluctuations will provide basic data for discussing cost management and profit management in public hospitals.

Since the above contributions are expected, the research question of this paper is to clarify the cost structure and cost fluctuations of public hospitals using congestion cost as a key concept. Specifically, we aim to answer the research question by conducting the following two types of analysis. First, in the analysis of cost structure, we follow Banker et al. (2014b) for public hospitals to examine what measures public hospitals take to deal with congestion costs. Specifically, by estimating equation (3) using data from public hospitals, we examine whether cost rigidity increases with the uncertainty of demand for health care. Then, in the analysis of cost variation, we attempt to directly examine the congestion cost by estimating equation (4) using the data of public hospitals as follows.

$$\log\left(\frac{\text{Cost}_{i,t}}{\text{Cost}_{i,t-1}}\right) = \beta_0 + \beta_1 \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) + \beta_2 \cdot \text{BOR}_{i,t} \cdot \log\left(\frac{\text{Revenue}_{i,t}}{\text{Revenue}_{i,t-1}}\right) \tag{4}$$

Here, the variable $\text{BOR}_{i,t}$ (abbreviation for bed occupancy rate) represents the bed occupancy rate of hospital i in year t. The relationship between this bed occupancy rate and congestion can be understood as follows. First, congestion arises from random fluctuations in the number of patients in situations where the bed occupancy rate is high (Balakrishnan & Soderstrom, 2000). However, random variation in the number of patients is a phenomenon that occurs independently of the occupancy rate. Therefore, we can assume that the probability of random variation in the number of patients is the same whether the occupancy rate is low or high. Therefore, with sufficient sample size, it is possible to obtain a subsample with a high occupancy rate and congestion and a subsample with a low occupancy rate and no congestion. As a result, the occupancy rate can be regarded as a proxy variable for the degree of congestion of hospital beds.

It is true that, from a practical standpoint, the hospitals to which urgent patients are transported may be those with low occupancy rates and big beds. However, since congestion is avoided in such hospitals due to surplus beds, congestion should not have occurred in the subsample consisting of hospitals with low occupancy rates. Based on these points, if β_2 in equation (4) is estimated to be positive, it can be interpreted as an increase in the variable cost ratio due to additional costs incurred by congestion.

3.2. Sample

In this paper, we use the Public Enterprises Survey Reports published by the Department of Public Enterprises, Ministry of Finance on its website to collect samples. These reports contain data on various types of public enterprises, such as water supply and electricity utilities. In the case of hospital enterprises, income statements by the entity and related non-financial information on medical services provided by local public entities are disclosed. Using these data, we estimate the analytical model shown in equations (3) and (4).

Medical revenue and non-medical revenue are revealed in the revenue section of the hospital's financial statement, and the amounts of hospitalization revenue and outpatient revenue are disclosed as medical revenue details. Medical expenses and non-medical expenses, on the other hand, are given in the expense section, and the details of medical expenses are the quantities of each expense, such as staff wages and material costs. In this paper, the hospital bed occupancy rate is used as a proxy variable for the degree of congestion of hospital beds, so it is desirable to use hospitalization revenue as $\text{Revenue}_{i,t}$ in equations (3) and (4). However, as previously stated, the expenses of inpatient and outpatient care are not published. As a result, the total amount of medical revenues and medical expenses are used in the study, taking into account the correspondence between costs and revenues. We'll use an index based on the average number of inpatients each day to account for demand uncertainty in each hospital. This indicator's precise calculating method will be discussed later. The "general hospital bed occupancy rate" disclosed in the "Report on Management Analysis" will be used for the occupancy rate of hospital beds.

The Public Enterprises Survey Reports include three types of public hospitals: general hospitals, tuberculosis hospitals, and psychiatric hospitals; however, due to the characteristics of hospitalization, we only used general hospital beds as our sample. As a result, we got an unbalanced panel data sample consisting of a maximum of 1,505 hospitals per year for a total sample size of 12,595 hospitals per year from 2005 to 2019.

The descriptive statistics of the sample collected by the method described above are shown in Table 1 below. There are a few missing values in the data. The reason for this is that the data for each hospital was collected by individual questionnaire, so it is assumed that there were some non-responses or invalid responses in the data collection.

4. Empirical Results

4.1. Analysis 1: Banker et al. (2014b) Follow-Up Study

By estimating equations in Analysis 1 on cost structure, we can see if public hospitals enhance cost rigidity to prevent congestion expenses (3). The majority of prior studies on cost rigidity used financial data disclosed by companies as a sample to quantify the variable. Because demand cannot be measured directly, sales are often used as a proxy variable in these studies. When the study's subject is a hospital, like in this case, the number of patients can be used to directly evaluate medical care demand and to index uncertainty. Holzhacker et al. (2012), who examined the cost structure of hospitals in a similar way to our study, used the number of patients to quantify the unpredictability of demand for medical care. In this study, the standard deviation of the logarithmic difference of "average daily inpatient admissions" by the hospital replaces the uncertainty of demand Uncert_i (the standard deviation of the logarithmic difference of revenue by firm) contained in equation (3). Demand unpredictability In accordance with the setting of this study, which focuses on public hospitals, Uncert_i in equation (3) is replaced by "risk of change in the occupancy rate of hospital beds." We followed Banker et al. (2014b) in determining the hospital's standard deviation. We set the requirement that the logarithmic difference of the "average number of patients admitted per day" must be at least 10. We examine the long-term impact of the risk of changes in hospital bed occupancy rates on the cost structure of public hospitals in this way.

The results of the analysis are shown in Table 2. To confirm the robustness of the results, the results estimated by both the pooled model and the fixed-effects model are included. According to the results of the analysis, the coefficient β_2 of the interaction term between the risk of change in the occupancy rate and the logarithmic difference in revenue is significantly negative in both the pooled model and the fixed-effects model. This means that as the risk of change in the occupancy rate increases, the degree of change in cost relative to the change in revenue decreases, and public hospitals adopt a so-called rigid cost structure.

The results show that the degree of cost rigidity increases with the uncertainty of demand in public hospitals to avoid congestion costs.

4.2. Analysis 2: Bed Occupancy and Cost Rigidity

In our cost-variation analysis, we examine whether congestion costs occur as a result of a higher hospital bed occupancy rate. Specifically, the ordinary least squares approach is first used to estimate equation (4). For comparison, Equation (1) is also estimated in the same way. If the interaction term 2 between the occupancy rate and the logarithmic difference in revenue is significantly positive as a result of the estimation of equation (4), it suggests that an additional cost, i.e., a congestion cost, is incurred as the occupancy rate, which is a proxy variable for the degree of hospital bed congestion, increases.

Table 1: Descriptive Statistics

	n	Average	Standard Deviation	1st Quartile	Median	3rd Quartile
Medical expenses (thousand rupees)	12,589	4,468,408	4,862,149	1,012,657	2,454,273	6,294,519
Medical service revenue (thousand rupees)	12,465	4,094,276	4,623,550	841,845	2,194,167	5,766,195
Average number of patients admitted per day (persons)	12,592	178	156.7	57	124	255
Bed occupancy rate (%)	12,345	73.7	16.2	65.3	77.0	85.3

Table 2: Estimation Results of Equation (3)

Coefficient	Variables	Pooling Model	Fixed Effects Model
β_0	(Constant term)	0.006** (0.002)	–
β_1	Logarithmic difference of revenue	0.603*** (0.032)	0.566*** (0.034)
β_2	Risk of change in bed occupancy rate x logarithmic difference in revenue	–1.115*** (0.237)	–0.976*** (0.263)
n		8,566	8,566
Degree of freedom-adjusted coefficient of determination		0.440	0.436

**$p < 0.05$, ***$p < 0.01$. The upper part of the values are estimates of the coefficients. Standard errors in parentheses in the lower panel are robust to clustering by two factors: hospital and year.

Congestion cost is defined as a high cost that arises when capacity utilization is high, as noted in the introduction. According to this, increasing the occupancy rate increases the probability of experiencing congestion costs, resulting in a larger cost change for the hospital. As a result, we use quantile regression analysis to estimate equation (4) to see if the interaction between occupancy rate and revenue fluctuations is more strongly influenced by higher cost fluctuations.

Table 3 shows the results of estimating equations (1) and (4) using the ordinary least squares method. We have included the results for both the case estimated by the pooling model and the case estimated by the fixed-effects model to assess the robustness of the results. According to the results of the analysis, the coefficient β_2 of the interaction term between the hospital bed occupancy rate and the logarithmic difference in revenue contained in equation (4) is estimated to be significantly positive in both the pooled and fixed-effects models. This result implies that as the bed occupancy rates increase, congestion costs increase as well.

According to the estimation results of equation (4) by the pooling model, the average variable cost ratio of the hospitals in the sample is calculated as $\beta_1\,(0.325) + \beta_2\,(0.234)$ × hospital bed occupancy rate.

Based on this, we estimate the specific variable cost rate for each quartile of the hospital bed occupancy rate (see Table 1): 0.478 for the first quartile (65.3%), 0.506 for the middle (77.0%), and 0.525 for the third quartile (see Table 1). (85.3 percent). When these values are compared by dividing by the variable cost rate without taking into account the occupancy rate, i.e. the estimated result of 1 in equation (1) (0.464), the occupancy rate in the first quartile becomes 1.03 times, 1.09 times in the middle, and 1.13 times in the third quartile. This means that forecasting the amount of change in costs based on the estimated findings of equation (1) will underestimate the amount of change in costs between the first and third quartiles of the hospital bed occupancy rate. Furthermore, the forecast difference is roughly 3% when the occupancy rate is in the first quartile. Still, it is 13% when the occupancy rate is in the third quartile, and the forecast gap grows as the occupancy rate rises.

Next, equation (4) is estimated by quantile regression analysis, as shown in Table 4. In this analysis, we estimated nine quartiles, from the first quartile (Q10) to the ninth quartile (Q90). For simplicity, only the estimated values of the coefficients are shown here.

According to the results of this analysis, the estimated values of the coefficient β_2 are all less than 0.1 from the first decile (Q10) to the third decile (Q30), indicating that the interaction term β_2 between the occupancy rate and the logarithmic difference in revenue has little effect on cost fluctuations. On the other hand, from the seventh decile (Q70), the estimated value increases sharply, reaching 0.677 at the ninth decile (Q90). These findings suggest that the relationship between bed occupancy rate and revenue fluctuations is more significantly influenced by bigger cost changes, implying the presence of congestion costs.

4.3. Checking the Robustness of Analysis Results

The findings of the studies in Tables 3 and 4 all point to the presence of congestion costs. The robustness of the results was confirmed in the least-squares estimation of Table 3 by examining using the fixed-effects model in addition to the pooling model. The following three forms of analysis are performed in this section to confirm the robustness from a more precise perspective.

The first step is to determine whether or not there is any endogeneity. The size and qualities of hospital beds may also have an impact on hospital cost variations and occupancy rates. As a result, we will do a reanalysis after inserting control variables for these parameters. The size of hospital beds was calculated using the logarithmically converted number of hospital beds. In terms of hospital bed characteristics, we used the average duration of stay and nursing staffing standard after logarithmic transformation.

Table 3: Estimation Results for Equations (1) and (4)

Coefficient	Variables	Pooling Model		Fixed Effects Model	
		Equation (1)	Equation (4)	Equation (1)	Equation (4)
β_0	(Constant term)	0.007*** (0.002)	0.006*** (0.002)	–	–
β_1	Logarithmic difference of revenue	0.464*** (0.016)	0.325*** (0.035)	0.436*** (0.018)	0.295*** (0.047)
β_2	Bed occupancy rate x logarithmic difference in revenue	–	0.234*** (0.059)	–	0.233*** (0.068)
n		10,978	10,763	10,978	10,763
Degree of freedom-adjusted coefficient of determination		0.435	0.439	0.443	0.445

***$p < 0.01$. The upper part of the values are estimates of the coefficients. Standard errors in parentheses in the lower panel are robust to clustering by two factors: hospital and year.

Table 4: Estimation Results of Equation (4) by Quantile Regression Analysis

Coefficient	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
β_0	–0.039	–0.020	–0.009	–0.001	0.006	0.013	0.020	0.030	0.047
β_1	0.539	0.573	0.458	0.358	0.342	0.293	0.203	0.102	–0.016
β_2	0.000	–0.023	0.095	0.212	0.213	0.264	0.371	0.506	0.677

The nursing staffing standard was utilized as a dummy variable that was set to 1 if the bed had a staffing ratio of 7:1 or 10:1, and 0 otherwise, to act as a proxy variable to indicate if the bed was an acute care bed (hereafter referred to as the acute care dummy variable). Then, these control variables were additionally introduced into both the intercept (β_0) and slope (β_1) of equation (4), and the analysis was conducted. As a consequence, the estimated value of 2 (standard error) for the pooling model was 0.247 (0.064) and for the fixed-effects model was 0.271 (0.066). As a result, compared to the results in Table 3, the reanalysis found only minor differences and no statistically significant differences.

The effect of hospital bed characteristics is examined further in the second analysis. Depending on the bed characteristics, the influence of bed occupancy rate as a proxy variable for the degree of bed crowding on cost variation may change. We separated the sample into an acute subsample (n = 8,602) and a non-acute subsample (n = 2,161) using the acute dummy variable stated previously and estimated equation (4) for each. As a result, the estimated value of 2 (standard error) for the acute subsample was 0.202 (0.060) for the pooled model and 0.180 (0.066) for the fixed-effects model. This result is comparable to that of the entire sample, with no statistical significance difference. The estimated value of 2 (standard error) for the non-acute subsample was 0.255 (0.108) for the pooled model and 0.302 (0.177) for the fixed-effects model. This result follows the same pattern as that shown in Table 3 for the entire sample. The fixed-effects model, on the other hand, showed a decline in significance (at the 10% significance level). The reduced sample size can be ascribed to the drop in significance because the estimated value of 2 is higher than that of the acute subsample. This implies that the impact of congestion on cost variation is stronger in non-acute beds than in acute beds.

The effects of hospital reorganization are not considered in the third type of analysis. When Hospital A combines with Hospital B to establish Hospital C, for example, Hospitals A, B, and C are regarded as separate entities in this study, and the impacts of such reorganization are largely controlled. We cannot, however, consider the situation in which Hospital A absorbs Hospital B and only Hospital A continues under the same name. As a result, any situations in which medical income increased more than 1.5 times from the prior year were considered outliers and were eliminated from the sample. In addition, hospitals for whom we were unable to collect observation data for 10 consecutive periods were omitted.

In summary, the results of the analyses reported in this paper are robust to the perspectives of the three types of analyses conducted here.

4.4. Discussion

The following are the characteristics of the cost structure and cost fluctuations of public hospitals as shown by Analyses 1 and 2. First, the findings of analysis 1 on cost structure revealed that the higher the probability of a change in hospital bed occupancy, the lower the degree of change in costs owing to revenue variations. This can be interpreted as: the higher the risk of changes in the occupancy rate, the more inflexible the pricing structure of public hospitals becomes to prevent congestion charges. The results of study 2 on cost fluctuations revealed that an increase in the bed occupancy rate, which serves as a proxy for the degree of bed congestion, leads to large cost fluctuations. This can be interpreted as the result of an increase in the variable cost ratio due to the effect of congestion costs that occur in situations where the occupancy rate is high. In addition, as the results of the quantile regression analysis showed, the larger the cost variation, the more strongly it was affected by the bed occupancy rate. These results suggest that although public hospitals have chosen a cost structure that avoids congestion costs, congestion costs have not been completely avoided.

Note that analysis 2 shows that ($\beta_1 + \beta_2$) in equation (4) does not exceed 1 in the estimated range. This means that increasing the occupancy rate to 100% will contribute to maximizing the profits of public hospitals. However, in reality, public hospitals need to bear not only medical costs, which are the subject of analysis but also non-medical costs. For bottom-line profit maximization, additional analysis is needed to determine whether congestion costs are also observed in non-medical costs.

6. Conclusion

First, we would like to point out the following two academic contributions of this paper. The first contribution is that it provides direct evidence for the existence of congestion costs: Banker et al. (2014b), and other related studies focus on the cost structure chosen to avoid congestion costs rather than directly observing congestion costs. In contrast, this paper succeeded in directly confirming the existence of congestion cost by using the hospital bed occupancy rate as a proxy variable for the degree of congestion in hospital beds. It should also be pointed out that this study showed that the research opportunities can be greatly expanded by devising the selection of the sample, as this study chose public hospitals as the sample. The second academic contribution comes indirectly from the findings of this study. In other words, the findings of this study indirectly show that retaining unused capacity and allowing a margin in the utilization rate has significance in avoiding congestion costs. Even though the cost of retaining unused capacity does not generate revenue, this cost avoids congestion costs to some extent. This provides new insights into the decision-making problem of unused capacity.

Following that, we'd like to highlight the following two practical implications for public hospital management that might be obtained from this paper. The first is that, while public hospitals choose a pricing structure that minimizes congestion costs, they do not totally avoid them. This gives fundamental information for public hospital management. To reduce the cost of congestion, it is vital to plan ahead of time for appropriate capacity. This entails constructing a cost structure in which the variable cost ratio is close to zero and fixed costs account for the vast majority of expenses. However, it should be noted that such a cost structure also increases the possibility of generating large deficits when earnings decline. The results of Analysis 2 also show that even when the occupancy rate is 100%, the variable cost ratio ($\beta_1 + \beta_2$ in Equation 4), which takes into account congestion costs, is below 1 on average and does not reach a level that would reduce profits. Even if congestion costs exist when the occupancy rate of hospital beds is high, the increase in revenue associated with the rise in the occupancy rate of hospital beds can be said to cover them. Second, the inefficiency of public hospitals has been highlighted in recent years, with recommendations for downsizing and reorganization. However, it should be noted that increasing the occupancy rate of hospital beds by reducing the number of beds and reorganizing hospitals also creates a situation where congestion costs are likely to occur. If plans to reduce the number of beds or restructure hospitals that do not take congestion costs into account are intended to increase occupancy rates, such plans may underestimate costs and, consequently, overestimate profits.

Any empirical study should not be extrapolated outside the sample's population. Finally, we'd like to bring out some of the study's shortcomings and make some recommendations for further research. To begin with, the existence of congestion costs was only established in the analysis of a public hospital sample, and it is unclear whether the same conclusion can be obtained for projects other than hospitals. As a result, the process of confirming the existence of congestion costs must be expanded to include other business organizations to ensure the conclusions' robustness. Second, variable costs are explained as activity costs that come from the execution of business operations in classical cost theory.

Congestion cost, the subject of this study, is a cost associated with traffic congestion that manifests itself as a rise in the variable cost rate. As a result, congestion cost implies that the number of management resources consumed by a unit of company activity increases, according to traditional cost theory. Future studies should focus on clarifying the process behind the increase in the amount of management resources required by congestion at the business activity level, as well as extending cost theory to include congestion costs. Third, if the reason for congestion costs is a minor problem or stumbling block that occurs in one part of the system but affects the entire system in a high capacity utilization area, the impact should be felt first in non-financial outcomes such as the entity's services and their quality.

The public hospitals examined in this study are not-for-profit organizations, and their goal is not to earn and share profits through business operations. In this sense, the loss in service and quality for public hospitals may be more problematic than the increase in accounting costs. As a result, it is vital to investigate the relationship between congestion and non-financial outcomes in the context of hospital management. Even if allowing a margin in the occupancy rate to prevent congestion charges is effective, more research on non-financial consequences is needed to decide what level of occupancy rate should be maintained.

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