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MANAGERIAL PERFORMANCE AND COST EFFICIENCY OF JAPANESE LOCAL PUBLIC HOSPITALS: A LATENT CLASS STOCHASTIC FRONTIER MODEL

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SUMMARY

The paper explores the link between managerial performance and cost efficiency of 617 Japanese general local public hospitals in 1999–2007. Treating managerial performance as unobservable heterogeneity, the paper employs a panel data stochastic cost frontier model with latent classes. Financial parameters associated with better managerial performance are found to be positively significant in explaining the probability of belonging to the more efficient latent class. The analysis of latent class membership was consistent with the conjecture that unobservable technological heterogeneity reflected in the existence of the latent classes is related to managerial performance. The findings may support the cause for raising efficiency of Japanese local public hospitals by enhancing the quality of management.

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KEY WORDS: hospital efficiency; stochastic frontier analysis; latent classes; management

1. INTRODUCTION

A considerable amount of applied research has been carried out to measure productive efficiency of hospitals in various countries (Hollingsworth, 2008; O'Neill *et al.*, 2008; Rosko and Mutter, 2008; Worthington, 2004). However, while studies carefully define inputs, outputs, and various environmental variables, only a few papers analyze the relationship between management and efficiency (e.g. OLS post-estimation analysis of stochastic frontier efficiency scores, with management measured as the share of administrative staff in total staff in Bosmans and Fecher, 1995). The common approaches of assessing the effect of ownership (Daidone and D'Amico, 2009; Barbetta *et al.*, 2007), provider incentive (Biorn *et al.*, 2010; Chang and Troyer, 2009), and managed care (Alexander *et al.*, 1998) on hospital efficiency only touch indirectly on certain management issues. This is regrettable because managerial performance needs to be taken into account when measuring efficiency. Indeed, the residual in productivity analysis reflects unobservable, immeasurable, or omitted factors (Griliches, 1996; Newhouse, 1994), which include heterogeneity of management (Bloom and van Reenen, 2010).

This paper explores the link between managerial performance and hospital efficiency. Our sample is Japanese local public hospitals, which constitute 10% of all hospitals and 65% of public hospitals in the country. Japanese local public hospitals are established by prefecture, city, town, village, or a union of several towns and villages. Universally Japanese local public hospitals have a shortage of doctors, so

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they have to overinvest in capital to maintain their role of public providers guaranteeing certain types of health care in local areas. Overinvestment in capital causes an incorrect input mix and often leads to a financial deficit, which has to be covered by central and regional government subsidy along with transfers from local governments (Yamada *et al.*, 1997). The heavy burden of hospital transfers on the budgets of local governments prompts academic analysts and policymakers to pay close attention to decreasing hospital deficits and enhancing the efficiency of Japanese local public hospitals. Studies estimating efficiency of Japanese local public hospitals demonstrate that government subsidy and quality indicators are associated with technical and cost inefficiency (Kanagawa, 2008; Nakayama, 2004; Fujii, 2001; Yamada *et al.*, 1997). While Japanese public hospitals have long been criticized for weak financial constraints and poor managerial efforts (Ikegami and Campbell, 1999; Iwane, 1976), to the best of our knowledge there are only two studies which look at the relationship between managerial characteristics and efficiency at these hospitals.[1] Kinoshita and Kaihara (2008a) demonstrated that data envelopment analysis efficiency scores increased at 4 out of 11 national hospitals which were transferred to other administrators, decreased at 1 such hospital, and remained the same at 6 such hospitals. Kinoshita and Kaihara (2008b) found that rank correlation between data envelopment analysis efficiency scores of local public hospitals[2] and 'management ratio' (defined as medical revenues divided by medical costs) equaled 0.7.[3] However, the two studies provide only limited assessment of the relationship between managerial performance and hospital efficiency. Indeed, the act of transfer analyzed in Kinoshita and Kaihara (2008a) does not necessarily imply a positive change in managerial practices. As for the approach in Kinoshita and Kaihara (2008b), it mimics a two-step procedure. In particular, it implicitly assumes that 'management ratio' is one of the environmental variables and that 'management ratio' is uncorrelated with inputs. However, these two assumptions may not necessarily hold. Arguably, financial parameters similar to 'management ratio' are only proxies for managerial practices, since the latter require a special methodology for their quantification (Bloom and van Reenen, 2010). Therefore, cautious interpretation of results is required when such financial parameters are treated as environmental variables. Moreover, financial parameters may be correlated with inputs, which would lead to inconsistent estimates.

This paper regards hospital managerial characteristics as unobservable technological heterogeneity and exploits stochastic frontier analysis (SFA), which relates efficiency to the distance to the frontier and enables incorporating unobservable technological heterogeneity in the frontier. The paper empirically applies a latent class (finite mixture) approach to a SFA of hospital cost efficiency. The motivation for using a latent class approach is the fact that managerial practices in our sample are unobservable. We assume that hospital management could be divided into a discrete number of types. Empirical support for this conjecture may be observed in the histograms of management scores (Bloom *et al.*, 2010), which suggest that while the distribution of management scores for manufacturers is continuous, hospital scores separate into several groups.

Assuming that managerial efforts are reflected in financial performance of hospitals, we employ a number of financial variables as correlates of the probability for latent class membership. Indeed, a unique series of surveys for over 3000 firms in 17 countries (Bloom and van Reenen, 2010; Bloom and van Reenen, 2007), for 121 hospitals in the UK (Bloom *et al.*, 2010), and for 1194 hospitals in the United States, United Kingdom, Canada, Sweden, Germany, France, and Italy (Dorgan *et al.*, 2010) demonstrated that aggregated management scores, encompassing 18 dimensions of managerial practices, explain the financial performance of firms, in general, and hospitals, in particular.

[1]The policy-oriented analysis of SFA or DEA scores for Japanese local public hospitals generally concentrates on the issue of government subsidies.
[2]The sample was 385 local public hospitals with general beds in 2004.
[3]In the context of the US hospitals, a similar analysis of correlation between stochastic frontier analysis efficiency scores and financial variables may be found in Rosko and Mutter (2010).

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Similarly, Japanese case studies reveal that methods of effective management provide a variety of ways to solve financial problems of local public hospitals (Higuchi, 2010; Kumazawa, 2010; Nabemi, 2010; Hisamichi, 2006). For example, educational seminars in the three prefectural hospitals in Miyagi prefecture inform medical staff about evidence-based management and accounting of capital flows and presumably help to reduce hospital deficits (Hisamichi, 2006). Weekly meetings in Kamiamakusa city hospital in Kumamoto prefecture assist to discover such means of decreasing costs as administering pre-scheduled tests earlier in the morning (Higuchi, 2010).

To the best of our knowledge, the paper becomes the first application of a latent class stochastic frontier model to the analysis of hospital efficiency. We use a latent class model since we believe that management practices may not be well captured by observable characteristics of hospital performance, available in administrative databases. Moreover, a latent class model with probabilities of class membership related to financial parameters does not impose any restrictions on the correlation between inputs and financial parameters. Therefore, our approach is more general than a two-step procedure similar to Kinoshita and Kaihara (2008b).

The study is an attempt to reveal a link between the quality of management and cost efficiency for a panel of Japanese general local public hospitals. Given the assumption of discrete latent class specification, our estimations showed that the hospitals separate into two latent classes, with cost inefficiency in 1999–2007 increasing in each of the classes. The analysis of latent class membership showed that the unobservable technological heterogeneity reflected in the existence of the two latent classes is related to financial parameters, which may be regarded as proxies for managerial performance. We believe that the findings may confirm the need to enhance managerial performance of Japanese local public hospitals.

It should be noted that, although SFA allows measurement of hospital efficiency and incorporation of unobservable heterogeneity through a latent class approach, it has two major limitations. First, SFA may cause potential bias due to endogeneity. Second, SFA fails to address the issue of reverse causality. Nonetheless, given the lack of data on managerial practices in Japanese hospitals,[4] an SFA model with unobservable heterogeneity can shed new light on the analysis of cost containment, efficient use of hospital inputs, and managerial performance. As for the issue of causality, Japanese case studies uniformly show that local public hospitals become cost efficient after introduction of effective managerial measures. We failed to find any instance of reverse causality, where an efficient hospital attracted better management. In fact, such a counter example would be extremely unlikely in Japan, which faces a lack of professionals in hospital management.[5]

The remainder of the paper is structured as follows. Section 2 employs Greene's (2002) SFA model with latent classes and Battese and Coelli's (1992) time varying inefficiency term. Section 3 outlines the results of estimations and conducts the analysis of latent class probabilities. Section 4 discusses the results in the context of recent reforms of Japanese local public hospitals, and section 5 concludes the paper.

2. A PANEL DATA STOCHASTIC COST FRONTIER MODEL WITH LATENT CLASSES

2.1. The model

The paper employs SFA (Aigner *et al.*, 1977; Battese and Corra, 1977; Meeusen and van den Broeck, 1977), which allows incorporating unobservable technological heterogeneity in the frontier (Greene, 2005, 2002). Moreover, if compared to an alternative non-parametric method – data envelopment analysis – SFA is less sensitive to outliers, allows including hospital-specific (environmental) variables, and distinguishes random error from inefficiency (Jacobs *et al.*, 2006).

[4]Data on managerial practices in Japanese local public hospitals are not available, so we cannot use other policy evaluation methods which could account for causal effects.

[5]Public health schools and business schools, which specialize in training of healthcare managers, are scarce in Japan.

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In contrast to previous models with individual heterogeneity in the stochastic frontier of Japanese local public hospitals (e.g. Takatsuka and Nishimura, 2008; Kawaguchi, 2008; Table I), the model in this paper accounts for technological heterogeneity assuming that poor management, high costs of adopting new technologies, and lack of information lead to inferior technologies (Tsionas, 2002). In particular, the model assumes that management styles may result in different hospital technologies. As there are no data quantifying management styles in Japanese local public hospitals, the paper uses a latent class stochastic frontier model (Greene, 2005, 2002). The model implies that inefficiency and its time profile depends on the unobservable type of management and varies across classes.

As hospitals are generally modeled as cost-minimizing rather than profit-maximizing economic agents,[6] this paper considers a stochastic cost frontier panel data model (1)–(5) with flexible trans-logarithmic cost function. Cost function homogeneity of degree one in prices is exploited by division of costs and all prices by a numeraire price (following Yamada *et al.*, 1997, in this case it is the cost of medicines and materials per bed, *pmed*).[7]

Cost inefficiency follows a time decaying pattern in the form of Battese and Coelli (1992). Time decaying assumption is justified by the fact that regardless of a particular model, increasing inefficiency is found in Japanese local public hospitals in late 1990s–early 2000s. Indeed, Takatsuka and Nishimura (2008) demonstrate that output inefficiency rose in 2001–2004. Kawaguchi (2008) shows that cost inefficiency increased in 1999–2003 and suggests an explanation for such a pattern.

Let

$$\begin{aligned}\ln \frac{C_{it}}{pmed}|j = \beta_{0j} + \sum_n \beta_{nj} \ln Y_{nit} + \sum_k \beta_{kj} \ln \frac{W_{kit}}{pmed} \\ + \frac{1}{2}\sum_k \sum_k \beta_{kkj} \ln \frac{W_{kit}}{pmed} \ln \frac{W_{kit}}{pmed} + \frac{1}{2}\sum_n \sum_n \beta_{nnj} \ln Y_{nit} \ln Y_{nit} \\ + \sum_k \sum_n \beta_{knj} \ln \frac{W_{kit}}{pmed} \ln Y_{nit} + \sum_l \beta_{lj} Z_{lit} + v_{it} + u_{it}\end{aligned} \tag{1}$$

$$u_{it}|j = \exp\{-\eta_j(t-T)\} \cdot U_i \geq 0 \ (\eta_j < 0 \text{ means increasing inefficiency over time}) \tag{2}$$

$$U_i|j \sim N^+(0, \sigma_{uj}^2) \tag{3}$$

$$v_{it}|j \sim N(0, \sigma_{vj}^2) \tag{4}$$

$$F_{i1} = \frac{\exp(\theta_1 + \theta_2 \cdot x_i)}{\exp(\theta_1 + \theta_2 \cdot x_i) + 1}, \quad F_{i2} = 1 - F_{i1}, \tag{5}$$

where i indicates hospital, t is time, T is the final time period, j is a latent class index ($j = 1,2$), n is the index for outputs, k is the index for prices, β-*s* are corresponding coefficients, η is the time decaying parameter in Battese and Coelli's (1992) model, C_{it} is the total hospital costs, Y_{nit} stands for outputs, W_{kit} denotes prices, Z_{lit} are hospital characteristics, F_{ij} are latent class probabilities in a multinomial logit form, x_i is a time invariant variable affecting latent class probabilities, v_{it} is the stochastic error term, and u_{it} is the inefficiency term.

The estimations of the model were conducted in LIMDEP 9.0, which calculates posterior joint probability of belonging to each latent class j for the whole period $t = 1 \ldots T$ (assuming

[6]The presence of government subsidies and transfers from the corresponding municipalities may question cost-minimizing behavior of Japanese local public hospitals. However, the sizes of the subsidies and transfers are negotiated and do not necessarily cover deficit in full.

[7]An alternative approach would be to treat price of medical materials as omitted variable (Fujii, 2001).

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Table I. Summary of the stochastic frontier analysis studies, measuring efficiency of Japanese local public hospitals

Authors	Method	Sample	Function	Inputs, outputs and hospital variables	Efficiency measures
Yamada *et al.* (1997)	SFA, cross-section	657 general local public hospitals out of all Japanese public hospitals in 1993	Cobb–Douglas cost function with squared and cubed outputs added for convergence	Costs: Total annual costs Outputs: inpatients/day (IV approach), outpatients/day Prices: labor: salary per employee, capital: (depreciation+interest)/bed Normalization by the price of materials Quality measures: teaching hospital dummy, standards of bed, nursing and meal, number of emergency beds Other hospital characteristics: general beds dummy, urban dummy, inverse bed occupancy rate, government subsidy/bed, government reimbursement for prescribed drugs & injections as percentage of their costs, beds, beds squared, bed cubed, examinations/100 patients, radiologies/100 patients	Mean cost inefficiency is 23.36%
Fujii and Ohta (1999)	SFA, pooled data and panel data	927 public hospitals, providing data in 1993–1995, out of all Japanese public hospitals in corresponding years	Translog cost function	Costs: Total annual costs Outputs: sum of inpatient admissions and outpatients/day, inpatient/outpatient ratio Prices: labor: salary per employee, capital: (depreciation+interest)/bookvalue Quality measures: dummy of compliance with at least one of nursing standards Other hospital characteristics: examinations/100 patients, general hospital dummy, emergency hospital dummy Linear homogeneity restriction in input prices	Mean cost inefficiency is 43.82% for pooled data; 12.05% (two component error term) or 13.5% (three component error term) for panel data
Fujii (2001)	SFA, cross-section	954–955 local public hospitals in 1993–1995 of all Japanese local public hospitals in corresponding years	Cobb–Douglas cost function with squared and cubed outputs	Costs: Total annual costs Outputs: inpatient admissions/day, outpatients/day Prices: labor: salary per employee, capital: (depreciation+interest)/bookvalue Quality measures: nursing, meal, bed standards Other hospital characteristics: examinations/100 patients, number of emergency beds, government subsidy/(patients/day), teaching, general hospital dummy, urban dummy, inverse bed occupancy rate. Battese and Coelli (1992) model	Mean cost inefficiency is 22.2% in 1993, 18.3% in 1994, 21.1% in 1995 (for truncated normal distribution)
Takatsuka and Nishimura (2006)	SFA, panel data	55 prefectural hospitals with over 300 beds selected out of all Japanese local public hospitals in 1999–2002	Translog production function	Inputs: doctors/bed, nurses/bed, depreciable equipment/bed Outputs: bed occupancy rate or average number of admissions and discharges/bed Inefficiency factors: outpatient/inpatient ratio, share of non-general beds, revenue/outpatient-day, revenue/inpatient, annual dummies, local population dummy, share of hospital's beds in the local district Battese and Coelli (1992) time invariant and time varying models	For output as bed occupancy rate technical efficiency is 0.762 in time invariant and 0.922–0.923 in time varying model ($\eta = 0.008$). For output as annual discharges per bed, technical efficiencies are correspondingly, 0.626 and 0.718–0.715 ($\eta = -0.005$). η-*s* are statistically insignificant

Table I. *Continued*

Authors	Method	Sample	Function	Inputs, outputs and hospital variables	Efficiency measures
Takatsuka and Nishimura (2008)	SFA, panel data	408 general local public hospitals (172 prefectural and 236 municipal), a random sample of 1/3 of all Japanese local public hospitals in 2000–2004	Translog production function	Inputs: doctors/bed, nurses/bed, depreciable equipment/bed Outputs: average number of admissions and discharges/bed Inefficiency factors: outpatient/inpatient ratio revenue/inpatient Hospital and other factors: annual dummies, compliance with local public enterprise act dummy, order entry system dummy, change in hospital type dummy, emergency hospital dummy, total beds, nursing standard dummy, profitability dummy Schmidt and Sickles's (1984) fixed effect, Battese and Coelli's (1995) time varying model, Greene's (2004) true fixed effect model	For all hospitals annual technical efficiencies are 0.414 in Schmidt and Sickles's (1984) model, 0.842–0.843 in Greene's (2004) true fixed effects model and 0.777–0.768 in Battese and Coelli's (1995) model; for hospitals without treatment beds annual technical efficiencies are 0.351 in Schmidt and Sickles (1984) model, 0.789–0.788 in Greene's (2004) true fixed effects model and 0.761–0.774 in Battese and Coelli's (1995). High rank correlations between efficiency estimates in Schmidt and Sickles (1984) and Battese and Coelli's (1995) models; low correlations between other efficiency estimates
Kawaguchi (2008)	SFA, panel data	862 general local public hospitals out of all Japanese local public hospitals in 1999–2003	Cobb–Douglas cost function	Costs: Total medical annual costs Outputs: inpatients/day, outpatients/day Prices: labor: salary per employee, capital: (depreciable capital–accumulated depreciation)/bed Quality measures: number of hospital's departments, nursing standards dummies Other hospital characteristics: beds, examinations/100 patients Greene (2004) true fixed effect model and fixed effect two way error component model	Cost efficiency is 0.821 in true fixed effect model and 0.825 two-way error component model. Annual mean cost efficiencies decrease with time in two-way error component model

independence of observations) as

$$P(j|i) = \frac{F_{ij} \cdot \prod_{t=1}^{T} P(i,t|j)}{\sum_{j=1}^{J} F_{ij} \cdot \prod_{t=1}^{T} P(i,t|j)}, \tag{6}$$

where F_{ij} is a prior class probability, $P(i,t|j)$ are probabilities of observation i conditional on class j in a period t, and $j = 1 \ldots J$ (Greene, 2007). Then, comparing $P(j|i)$ for all j the most probable latent class j^* and inefficiencies $u_{it}|j^*$ are estimated. Mean inefficiency is estimated in the form of Jondrow *et al.* (1982).

2.2. The data

The data employed in the analysis are nine annual surveys of all local public hospitals in Japan (The Yearbook of Local Government Enterprises, Hospitals, Vol. 47–55, 1999–2007 fiscal years, Chihou kouei kigyou byouinhen), published by the Department of Local Finance of the Ministry of Internal Affairs and Communications (Soumusho jichi zaiseikyokuhen).[8] The length of panel is justified by data availability in electronic form.

Of the 2007 sample of 957 local public hospitals, 879 hospitals existed within 1999–2007 and returned a questionnaire every year. 833 hospitals had the status of general hospital throughout 1999–2007.[9] 49 of them were classified as general, yet provided exclusively specialized care.[10] This study excluded observations with salaries of administrative staff, nurses, junior nurses or technicians above salaries of doctors; with average number of exams less than 0.1 per patient;[11] with average length of stay of over 70 days (0.05% of the final sample) or less than 6 days[12] (0.05% of sample); and with bed occupancy rate over 100%.[13] This led to a balanced panel of 617 general public hospitals in 9 years.[14]

While the previous studies (Table I) considered nursing standards (established by the Ministry of Health, Labor, and Welfare) as a quality characteristic, this paper uses Japan Council for Quality Health Care data (2009) on hospital accreditation. The program of voluntary accreditation of Japanese hospitals started in 1997; quality standards are being updated, and as of April 2011 version 6.0 of the corresponding hospital questionnaire was in use. Yet, as of April 2011, only 28.8% of inpatient institutions had quality accreditation. The low prevalence of coded diagnoses and procedures, and the voluntary character of accreditation program have become major obstacles to hospital's applying for quality accreditation. Seeking accreditation may sometimes be influenced by the decision of other hospitals in a given municipality to apply for accreditation. In this analysis, quality dummy equals unity if the hospital was given accreditation by the corresponding year. It should be noted that Spearman rank correlation between accreditation dummy and nursing standards rank variable (numbers of patients per nurse, nine categories) proved to be significant at 0.01 level in each analyzed year.[15]

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[8]Annual public hospital surveys are implemented within the annual research of other regional and municipal enterprises in a number of economic sectors.

[9]In various years two other general hospitals in the database changed their status.

[10]Specializing on cancer rehabilitation, adult diseases, ER medicine, brain blood, maternity, child health care, circulatory organ and apparatus respiratorus.

[11]Absence of examination during outpatient visit usually corresponds to repeated visits, which are mostly related to refilling prescriptions.

[12]With usual hospitalizations in Japan lasting at minimum a week, shorter stays are associated with ruled out illnesses (Evans *et al.*, 2007) or with preliminary diagnostics and further transferring to specialized hospital.

[13]Excluding these observations (most probably related to a rounding error or a special type of diagnostics provided in hospital on a day-service basis) does not change the results of estimations.

[14]In some years the panel includes from 1 to 4 hospitals with missing values for the number of examinations per patient. Efficiency scores in corresponding years are not estimated for these hospitals.

[15]This corresponds to Newhouse's (1970) suggestion that personnel/patient ratio might be one of quality indicators and justifies usage of nursing standard variables in other studies of Japanese public hospital efficiency.

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The data on the number of hospital departments (as of 2009) and on hospital's location come from 'Handbook of Hospitals', which contains hospital name, address, and the list of departments.

2.3. Output, price, and hospital variables

As actual outputs of hospital's activity – changes in patients' health – are commonly unobservable, the proxies for outputs in frontier studies generally include the numbers of outpatient visits, admissions, discharges, and patient-days. The database on Japanese local public hospitals does not report the number of admissions, giving instead the number of inpatients a day. Following previous Japanese literature and considering both numbers of inpatients and outpatients[16] a day as outputs could not be implemented due to high correlation of these variables in the sample. As for hospital discharges, the database allows calculating this variable as an average of annual admissions and actual discharges (Takatsuka and Nishimura, 2006). Estimated in such a way, 'discharges' were similarly correlated with the number of outpatients.[17] Another possible measure, patient-days, was also strongly correlated with the number of outpatients. Consequently, to capture multi-product character of hospital production function, the paper follows Fujii and Ohta (1999) and uses the sum of inpatient and outpatients cases (a day) and the ratio of outpatients to inpatients. It should be noted that the database does not report any variable directly or indirectly related to casemix, which brings certain limitations to interpreting the results of the empirical analysis.

Labor price is the earnings of an employee; capital price is the sum of depreciation and interest per bed.[18] Both these prices may be assumed exogenous in the framework of Japanese local public hospitals. Total cost and prices are normalized by the price of medicines (cost of medicines and materials per bed). An implicit assumption beneath this normalization states that 'volume' of medicines and medical materials per bed is constant.

Following Yamada *et al.* (1997), specialized (non-general) hospitals are not analyzed;[19] hospital characteristics include government subsidy; severity of illness (measured as the number of examinations per patient); drug margin rate; teaching and urban dummies. Hospital profitability dummy (Nakayama, 2004), bed occupancy rate (Fujii, 2001; Yamada *et al.*, 1997), subsidy from regional government and the dummy for prefectural hospitals were included in the list of covariates (Table II).[20] Although the total number of beds is sometimes regarded as one of explanatory variables, this study did not consider it as a regressor. Similarly, the paper uses the share of emergency beds instead of their total number. Indeed, justification for treating the total number of beds as a regressor is the desire to make it a proxy for capital stock (Wagstaff, 1989). The cost function in this paper, however, does not require variables accounting for the amount of inputs. Furthermore, the price of capital is introduced explicitly and does not need to be approximated by the capital value or by the number of beds.

3. EMPIRICAL RESULTS

3.1. Estimating stochastic cost function for each latent class

All variables in the stochastic cost function were rescaled to be in the range of 0 to 1. The maximum number of classes that could be disentangled by the software was three (with four classes LIMDEP

[16]The data for outpatient *visits* are not available in the database.
[17]Taking the logs of these output variables did not allow to decrease the value of correlation coefficient appreciably.
[18]Fujii (2001), Fujii and Ohta (1999) use book value instead of the total number of beds as denominator. While their approach may be regarded as better justified, the post-1999 data do not allow computing capital book value for each hospital.
[19]As cancer hospitals and some other specialized hospitals are considered 'general', the sorting was implemented both by variable 'hospital type' and by hospital name.
[20]Owing to the absence of casemix variable, we could not adjust the average length of stay and therefore, did not employ it as one of hospital characteristics.

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Table II. Definition and descriptive statistics of variables

Variable	Description	Obs	Mean	St. Dev.	Min	Max
PAT	Sum of inpatients and outpatients per day, th.	5553	0.840	0.639	0.051	4.578
OI	Ratio of outpatients to inpatients	5553	3.314	1.198	0.409	16.111
STATUS	= 1 if in non-profitable area, 0 otherwise[a]	5553	0.171	0.376	0	1
TEACH	= 1 if has affiliated nursery or junior nursery school, 0 otherwise	5553	0.068	0.253	0	1
ACCRED	= 1 if has Japan Council for Quality Health Care accreditation, 0 otherwise	5553	0.169	0.375	0	1
PREF	= 1 if prefectural or designated city hospital, 0 otherwise	5553	0.200	0.400	0	1
RURAL	= 1 if town or village hospital (as of 2007), 0 otherwise	5553	0.280	0.449	0	1
GENERAL	= 1 if has only general beds, 0 otherwise	5553	0.495	0.500	0	1
GOVS	Annual central government subsidy per bed, yen	5553	0.019	0.057	0	1.344
REGS	Annual regional government subsidy per bed, yen	5553	0.037	0.163	0	2.547
DRUG	Drug margin rate = government reimbursement of the cost of prescribed drugs and injections/ the cost of prescribed drugs and injections	5553	1.129	0.135	0.353	5.233
EXAM	Number of examinations per patient	5543	2.643	1.422	0	9.022
ERSHARE	Share of emergency beds in the total number of beds	5553	0.035	0.039	0	100
BO	Bed occupancy rate	5553	77.799	13.456	15	100
DEPART	Number of departments in a hospital	5553	13	7	1	34
BED	Total number of beds	5553	261.925	193.418	24	1082
COST	Annual total cost, mln. yen	5553	4884	4515	267	29 700
PL	Labor price = annual salary of a hospital employee, th. yen	5553	7175	667	4377	10 073
PMED	Annual cost of medicines and materials per bed, th. yen	5553	3890	1737	461	12 056
PK	Capital price = (annual depreciation + annual interest)/bed, th. yen	5553	1494	929	65	6414
OTHERSH	Share of revenues from other sources in medical revenues, percent	5540	14.683	11.646	0	120.9
LABORCOST	Labor cost ratio = 100*labor costs/medical revenues	5553	58.291	11.707	33.8	153.2
MEDREV	Medical revenues ratio = 100*medical revenues/medical costs	5553	90.691	9.802	44.1	120.6

[a]A hospital is situated in a non-profitable area if: (1) it has fewer than 100 beds (since 2009, relaxed to 150 beds) or fewer than 100 inpatients a day in the previous year; (2) the number of outpatients a day was less than 200 in the previous year; (3) there is at most only one other general hospital in the local municipal area or in the area of 300 km^2 (relaxed to the distance to another general hospital is over 15 km, or another general hospital exists in other locality').

failed to converge). Using AIC, BIC, and the Greene likelihood ratio test (Greene, 2007), the optimal number of classes was determined to equal two.

The results of the estimations indicate that the time decaying parameter η is negative and significant for both classes, which implies increasing cost inefficiency in each (Tables III and IV). A hint at explaining this phenomenon may be found in Kawaguchi (2008), who discovered that increasing cost inefficiency is a result of the aggregation of the two patterns: time invariant inefficiency for the top 10 efficient hospitals and rapidly increasing inefficiency for the bottom 10 efficient hospitals.

Our baseline model considers number of hospital departments and a constant as time invariant variables, explaining the first latent class prior probabilities. The positive and significant coefficient of the number of departments attests to higher probability of multi-departmental hospitals to be attributed to the first, more efficient latent class.

Mean inefficiency for the whole sample is 0.074. The value is lower than estimates in the other SFA models for Japanese local public hospitals (Table I). Accreditation and teaching status were found to have positive estimated coefficients.The negative sign of the coefficient for hospital profitability status corresponds to Takatsuka and Nishimura (2008). Government subsidy is positively significant in the first latent class, which corresponds to Fujii (2001) and Yamada *et al.* (1997). Regional subsidy has different signs of estimated coefficients: positive for the first latent class and negative (albeit insignificant) for the second latent class. The negative sign implies that in case of less efficient hospitals regional government subsidy does not contribute to growing costs. Note that it is necessary to hedge oneself in interpreting the influence of subsidies on total costs. Indeed, the issues of possible endogeneity and reverse causality which are not addressed in the framework of the SFA model limit the results of the analysis.

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Table III. Estimates of stochastic cost function for dependent variable ln($C/pmed$)

	Latent class 1	Latent class 2
ln(pat)	1.0928*** (0.0432)	0.2630** (0.1312)
ln(oi)	−0.4766*** (0.0477)	−1.4768*** (0.1104)
ln(pk/pmed)	0.7368*** (0.0443)	1.2023*** (0.1144)
ln(pl/pmed)	−0.3795*** (0.0677)	−0.9075*** (0.1269)
ln(pat)*ln(pat)	0.0432* (0.0257)	−0.2702*** (0.0621)
ln(oi)*ln(oi)	−0.1528*** (0.0086)	0.0837*** (0.0167)
ln(pk/pmed) ln(pk/pmed)*	0.1088*** (0.0035)	0.1410*** (0.0103)
ln(pl/pmed) ln(pl/pmed)*	0.9207*** (0.0534)	0.9422*** (0.0872)
ln(pat)*ln(oi)	−0.0690*** (0.0178)	0.2278*** (0.0505)
ln(pat)**ln(pk/pmed)*	−0.0615*** (0.0139)	−0.1554*** (0.0333)
ln(pat)**ln(pl/pmed)*	−0.1464*** (0.0242)	0.3618*** (0.0687)
ln(pk/pmed) ln(pl/pmed)*	−0.4509*** (0.0337)	−0.7686*** (0.0812)
ln(oi)**ln(pk/pmed)*	−0.0164*** (0.0051)	−0.0319*** (0.0114)
ln(oi)**ln(pl/pmed)*	0.1834*** (0.0355)	0.8008*** (0.0604)
Status	−0.0022*** (0.0008)	−0.0104*** (0.0022)
Teach	0.0038*** (0.0010)	0.0225*** (0.0067)
Accred	0.0005 (0.0004)	0.0064*** (0.0020)
Prefectural	0.0070*** (0.0014)	0.0639*** (0.0048)
Govs	0.0111*** (0.0029)	0.0055 (0.0214)
Regs	0.0688*** (0.0073)	−0.0447 (0.0343)
Drug	−0.0076 (0.0050)	−0.0264 (0.0183)
Exam	0.0123*** (0.0016)	0.0014 (0.0047)
Ershare	0.0133 (0.0096)	−0.0081 (0.0095)
Rural	−0.0090*** (0.0014)	−0.0305*** (0.0054)
General	−0.0011*** (0.0004)	−0.0049*** (0.0010)
BO	−0.2037*** (0.0017)	−0.1317*** (0.0042)
Constant	0.0430*** (0.0138)	0.3371*** (0.0361)
Time decaying parameter η	−0.0449*** (0.0013)	−0.0095*** (0.0012)
Prior class probabilities	0.67	0.33
Estimated prior probabilities for class membership		
Constant	−0.3060 (0.2387)	
Depart	2.7413*** (0.7039)	
Log-likelihood	16 382	
Years	9	
Hospitals	617	

***$p<0.01$, **$p<0.05$, *$p<0.1$. Standard errors in parentheses.

Table IV. Mean cost inefficiency estimates by year

Year	Latent class 1	Latent class 2
1999	0.038	0.124
2000	0.040	0.125
2001	0.042	0.126
2002	0.044	0.128
2003	0.046	0.129
2004	0.048	0.130
2005	0.050	0.131
2006	0.052	0.132
2007	0.055	0.134
All years	0.046	0.129
Hospitals	408	209

The cost elasticities with respect to total number of patients at sample means equal 1.02 for the first latent class and 0.22 for the second latent class. This implies the absence of economy or diseconomy of scale for the first, more efficient latent class.

3.2. Hospital performance parameters and the probability of latent class membership

To test the assumption that latent classes reflect unobservable factors related to hospital management, we expanded our baseline model and added hospital performance characteristics as variables, affecting the prior probability for latent class membership in (5). Two financial indicators listed in the Handbook on Management of Local Public Hospitals (Jichitai byouin keiei handobukku, 2007) were used as hospital performance characteristics. These indicators are: share of revenues from other sources (i.e. transfers and subsidies) in medical revenues, and labor costs divided by medical revenues.[21] The third indicator of the Ministry of Internal Affairs and Communications (2010) presented medical revenues divided by medical costs.[22] Owing to correlation between these variables, we considered three models, each with only one of the variables (denoted models '*a*', '*b*', and '*c*').

As latent class membership is assumed to be constant within the whole 9-year period, (5) provides for only time invariant characteristics affecting the prior probability of latent class membership. We, therefore followed the common approach in the empirical literature with latent class panel data models (Bago d'Uva and Jones, 2009; Bago d'Uva, 2005) and used average values of hospital performance characteristics. However, inclusion of annual means of variables that alter over time in (5) involves an approximation. To test the robustness of the estimates, we conducted the following regression analysis: posterior probability of belonging to the first, more efficient latent class – measured in the baseline model in (6) – was regressed on the annual means of financial performance variables.[23]

The results of the analyses (Tables V and VI) uniformly reveal that covariates, which are negatively related to effective management (share of revenues from other sources in medical revenues; labor costs divided by medical revenues), have negative and significant estimated coefficients in explaining the probability of belonging to the first, more efficient latent class. However, medical revenues divided by medical costs – a covariate positively related to effective managerial performance – has a positive and significant estimated coefficient. The latter result is similar to Kinoshita's and Kaihara's (2008b) positive and significant correlation coefficient between efficiency scores and 'management ratio'.

It should be noted that our analysis with financial variables affecting latent class membership is silent about causality. However, the findings for seven developed countries in Dorgan *et al.* (2010) and Bloom *et al.* (2010), as well as Japanese case studies demonstrate that financial performance variables of hospitals are related to managerial practices. So the significance of financial variables in our estimations shows that separation into latent classes reflects managerial heterogeneity.

4. DISCUSSION

The issue of hospital management is commonly raised at meetings of the Japanese Hospital Association and in professional literature (e.g. Handbooks on Management of Local Public Hospitals, journals *Hospital Management* and *Journal of Japanese Hospital Association*). Yet, the problems of local public hospital efficiency in general and the quality of management in particular have been hardly addressed in the recent Japanese health care reforms. The guidelines on gradual changes of local public hospitals appeared only in December 2007 (Ministry of Internal Affairs and Communications, 2007).

Low incentives of Japanese local public hospitals and limited knowledge of the applicability of various managerial tools in case of a particular institution may be regarded as the major obstacles to

[21]The Handbook of Hospital Management lists the share of bad debts in medical revenues as number one management indicator. It is defined as current liabilities (current capital – balance carried over to the next year). In this paper it could not be calculated because corresponding data are available only at the aggregate level of municipality.
[22]The three indicators are measured in percentage terms; see Table II for definitions and descriptive statistics.
[23]We could not follow the common pattern (e.g. Deb and Trivedi, 2002) and take the log of posterior probability as the dependent variable, since due to rounding LIMDEP reported the probability of belonging to the more efficient latent class exactly equal to zero for a number of observations.

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Table V. Estimates of stochastic cost function for dependent variable ln(*C*/*pmed*)

	(a)	(b)	(c)
Medrev	4.15*** (0.72)		
Othersh		−3.50*** (0.77)	
Laborcost			−4.49*** (0.79)
Depart	1.56** (0.72)	1.89*** (0.71)	1.58** (0.72)
Constant	−2.66*** (0.49)	0.63** (0.31)	1.38*** (0.36)
Log-likelihood	16 402	16 392	16 401
Years	9	9	9
Hospitals	617	617	617

Coefficients of the variables influencing the probability of latent class membership .***$p<0.01$, **$p<0.05$, *$p<0.1$.
Note: See definition of variables in Table II. Standard errors in parentheses. The estimates of the coefficients for the cost function variables are omitted.

Table VI. Explaining the posterior probability of belonging to the more efficient latent class

	(a)	(b)	(c)
Medrev	0.92*** (0.11)		
Othersh		−0.81*** (0.13)	
Laborcost			−0.96*** (0.12)
Constant	0.04 (0.08)	0.81*** (0.03)	0.92*** (0.04)
Adj R^2	0.10	0.06	0.09
Years	9	9	9
Hospitals	617	617	617

***$p<0.01$, **$p<0.05$, *$p<0.1$.
Note: OLS regression. See definition of variables in Table II. Standard errors in parentheses. According to the results of Breusch–Pagan heteroskedasticity test, robust standard errors are estimated for the models *a* and *c*.

enhancing managerial performance. Indeed, there is evidence of high effectiveness of simple management measures, when they are introduced. For example, establishing specialized units, organizing check-up rooms, and holding a 'hospital day' attracts patients to Ako city hospital in Hyogo prefecture and therefore, provides young doctors with the possibility to treat a variety of illnesses (Nabemi, 2010). Good management may be related to using bonuses as an instrument for regulating work incentives (Nabemi, 2010) or as a tool to cut labor costs (e.g. through an agreement to decrease bonuses for all staff except for doctors, Higuchi, 2010).

The quality of managerial performance at local public hospitals is associated with the unobservable ability of the corresponding local government to cover deficits for its local public hospitals. When the burden of deficit becomes high, local governments may change heads of hospitals; transfer hospitals to private sector (allowed since 2003); appoint a private firm as the designated manager for a hospital (allowed since 2006); transfer prefectural hospitals to the level of cities, towns, and villages; merge hospitals or restructure them into clinics; replace total budget accounting (partial compliance with the Local Government Law) by introducing detailed accounting for various expenditures (full compliance with the Local Government Law).

Our analysis demonstrated that the probabilities of latent class membership are related to financial performance variables, which may be treated as proxies for managerial characteristics. The finding may justify the need for managerial reforms, reflected in a number of recent policy initiatives. Indeed, the September 2003 amendment to the Local Government Law deals with the possibility of appointing a private firm to directly manage financially weak local public enterprises (including hospitals). Similarly, the structural reform of municipal finances (adopted in June 2007) aims at replacing the subsidy per bed with a subsidy per actually occupied bed. This makes hospitals raise their profitability by reviewing the structure of their beds (Kanagawa, 2008), especially since new bed categories were introduced for better characterization of hospital activities (treatment beds in 2003, and rehabilitation and complicated condition beds in 2006).

The period from July to November 2007 saw continuous round-table discussions, organized by the Ministry of Internal Affairs and Communications ahead of final ratification of guidelines for reform of local public hospitals. After the guidelines were adopted in December 2007, regular updates on measures carried out at each Japanese local public hospital were provided and circulated in public. Monitoring of hospital performance was conducted in 2009 through a comprehensive survey of organization and management at each local public hospital. Finally, in June 2009 the Ministry started a regular executive seminar analyzing cases of managerial reforms at local public hospitals.

It should be noted that in terms of observable indicators of hospital performance, good management is commonly regarded as the ability of a local public hospital to have a low ratio of labor costs to medical revenues (below 50%). Yet, the indicator does not constitute a hard and fast rule. For example, labor costs are 48% in central hospital in Iwate prefecture. However, the hospital cannot be considered efficient by industry standards since it operates with a deficit from the cost of doctor trips to provide care in remote areas; expenditures on research seminars organized at hospitals; depreciation and interest payments on debt due to building and facility construction (Koyamada, 1995). Consequently, although this paper demonstrated that the labor cost variable becomes negatively significant in explaining the probability of belonging to the first, more efficient latent class, cautious conclusions need to be drawn from these empirical estimations.

Another limitation of the analysis is the inability to test for the robustness of the stochastic cost frontier model with latent classes, or to have a formal test rejecting the hypothesis that managerial characteristics determine the division into latent classes. Moreover, the absence of variables dealing with casemix in the database does not allow addressing the issue of non-managerial heterogeneity in the stochastic frontier.

5. CONCLUSION

The paper employed latent class SFA to reveal the impact of managerial characteristics on cost efficiency of 617 Japanese general local public hospitals in 1999–2007. Using the assumption of a discrete latent class specification, the latent class stochastic frontier model (Greene, 2002) with Battese and Coelli's (1992) time varying inefficiency term demonstrated that hospitals separate into two latent classes.

The estimations showed a steady increase in cost inefficiency of Japanese general local public hospitals in 1999–2007 in each of the two latent classes. Financial parameters related to better managerial performance were found to be positively significant in explaining the probability of belonging to the more efficient latent class. This probability was positively related to the ratio of medical revenues to medical expenditures, and negatively related to the share of revenues from other sources in medical revenues, and to the ratio of labor costs to medical revenues.

The analysis of latent class memberships was consistent with the conjecture that unobservable technological heterogeneity reflected in the existence of the latent classes is associated with managerial performance. The findings may support the cause for raising efficiency of Japanese local public hospitals by enhancing the quality of management.

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CONFLICTS OF INTEREST

The research was implemented under the Japanese government (MEXT) scholarship in 2007–2010. There are no potential conflicts.

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