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A Long Term Evaluation of the Japanese Medical Payment System for Cataract Surgeries: Did the Medical Policy Reduce the Long Hospital Stay in Japan?

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Abstract

In this paper, we conducted a long term survey of the cataract surgeries. The sample period was about 7 years, from July 2005 to March 2012. We evaluated the effects of three revisions of the medical payment system that were done in 2006, 2008 and 2010. For the analysis, the Box-Cox transformation model and Hausman test using Nawata's estimator were used for the length of stay (LOS) in hospitals, and the ordinary least squares method was used for the non-inclusive (mainly payments for surgeries) payments. We analyzed a dataset of 51,054 patients obtained from 60 hospitals (Hp1-60) where more than 300 one-eye cataract surgeries were performed during the period. For the LOS, we found that only the 2008 revision had significant impact on shortening the LOS but the other two did not. We also found very large differences among hospitals even after eliminating effects of patients' characteristics and type of principle diseases as previous studies. For non-inclusive payments 2006 and 2008 revisions had significant impacts and the differences among hospitals were much smaller than those of the LOS.

Keywords

DPC/PDPS, Inclusive Payment System, Cataract, Length of Stay (LOS), Box-Cox Transformation Model, Hausman Test

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1. Introduction

A medical inclusive payment system based on the Diagnosis Procedure Combination (DPC), called the DPC/PDPS (DPC/per diem payment system) [1], was introduced in 2003 for 82 special functioning hospitals. From April 2004, general hospitals could join the DPC/PDPS. Under the DPC/PDPS, the medical payments consist of two different parts. One is inclusive payments based on the DPC codes and Length of Stay (LOS) in hospitals (hereafter, inclusive payments), and the other is non-inclusive payments based on the conventional fee-for-service system (hereafter, non-inclusive payments). In principle, the first one mainly covers the "hospital fee" that is necessary to operate the hospital, and the second covers the "doctoral fee" for medical treatments such as surgeries. For the inclusive payments, three periods, Periods I and II and the Specific Hospitalization Period, and per diem payments are determined by DPC codes, and per diem payments become smaller as the LOS becomes longer. If the LOS exceeds the Specific Hospitalization Period, the inclusive payment goes back to a conventional fee-for-service base. For details of the DPC and DPC/PDPS, see Nawata *et al*. [2]. The joining DPC/PDPS has not been obligatory, and a hospital can freely choose to join the DPC/PDPS or not if it satisfies necessary conditions [3]. However, according to Central Social Insurance Medical Council [4], as of April 2014, 1585 hospitals had joined the DPC/PDPS and additional 278 were preparing to join the system (hereafter, DPC hospitals). The DPC hospitals comprised 24.9% of the 7483 general hospitals and had 511,439 beds, which accounted 57.0% of the total (897,749) beds in all general hospitals, and the likelihood of DPC participation increased with hospital size. The DPC hospitals are required to computerize their medical information, it has become possible to analyze a large scale dataset which includes information of many patients, various diseases and treatments from many hospitals. The DPC/PDPS has been revised by every second year after 2004. Therefore, evaluations of revisions are very important for the efficient use of medical resources in Japan.

In this paper, we evaluate the effects of the 2006, 2008 and 2010 revisions of the medical payment system on the Length of Stay (LOS) and non-inclusive payments of cataract surgeries (Since actual inclusive payments to hospitals may be different for identical treatments, we analyzed the LOS rather than the inclusive payments). The sample period was about 7 years, from July 2005 to March 2012. In case of cataract surgeries, the portions of the inclusive and non-inclusive payments are about one-third and two-thirds, respectively. According to the survey of the Ministry of Health, Labour and Welfare [5], 79,192 cataract surgeries were done for 59,318 cases and their direct costs were 8.75 billion yen in June 2013. This means that nearly one million cataract surgeries and over 100 billion yen are spent annually. Although the effect of the single revision on the LOS was evaluated [6], analyses of long term evaluation of the revisions on the LOS and the non-inclusive payments have not been studied.

Among OECD countries, most cataract surgeries were performed on a day-case basis, without staying hospital after surgery (hereafter, day surgery), due to advances of medical technology and better anasthetics [7]. Percentages of day surgeries of many OECD countries exceeded 95% in 2011 [7]. In the cataract surgeries, "a dirty natural lens is removed, and then replaced by an artificial lens, called an intraocular lens (IOL)" [8]. The surgery will typically take less than 15 minutes per eye [9]. Trivedi *et al*. [10] reported that the length of hospital of cataract surgery could be reduced to an average of 3 hours and 37 minutes. Atalla *et al*. [11] surveyed data of 671 cataract patients in an Australian hospital. 226 (33.4%) patients were hospitalized overnight. But they conclude that "many patients who are hospitalized overnight could be safely treated as day cases". Fedorowicz, Lawrence and Guttie [12] also reported that there was no significant difference in outcome or risk of postoperative complications between day surgeries and surgeries with hospitalization. Even in an old study, Ingram *et al*. [13] reported that only 13% patients preferred to stay hospital after the surgeries among 501 cataract cases.

On the other hand, the long LOS for cataract surgeries in Japan was been very long. In our original dataset, there were 56,364 one-eye cataract surgery (just one eye was operated in a single hospitalization) cases. Among one-eye surgeries, only 1.7% of patients were day surgeries and average length of stay (ALOS) was 3.82 days. The LOS shows a fat tailed distribution on the right hand side.

Therefore, for the analysis of the LOS, the Box-Cox [14] transformation model (hereafter, BC model) is used as previous studies. The maximum likelihood estimator under the normality assumption (hereafter, BC MLE) is used for the estimation of the BC model. The BC MLE is generally inconsistent unless the "small σ" assumption described in Bickel and Doksum [15] and the error terms are independent and identically distributed (i.i.d.) random variables. Nawata [16] proposed semi-parametric estimators of the BC models. Using Nawata's estimator, we first test the BC MLE to determine whether or not we can use the BC MLE for the estimation of the BC model by the Hausman [17] test.

2. Estimators and Tests of the BC Model

2.1. BC Model

Suppose that LOS of patient t is given by the BC model:

$$z_t = x_t'\beta + u_t,\ y_t \geq 0,\ \ t = 1, 2, \cdots, T, \tag{1}$$

$$z_t = \begin{cases} \dfrac{y_t^{\lambda} - 1}{\lambda}, & \text{if } \lambda \neq 0, \\ \log(y_t), & \text{if } \lambda = 0, \end{cases}$$

where y_t is the LOS, x_t and β are the k-th dimensional vectors of the explanatory variables and coefficients, respectively, and λ is the transformation parameter. The likelihood function under the normality assumptions is given by

$$\log L(\theta) = \sum_t \log f_t(\theta), \text{ and } \log f_t(\theta) = \log \phi\{(z_t - x_t'\beta)/\sigma\} - \log\sigma + (\lambda - 1)\log y_t, \tag{2}$$

where $\theta' = (\lambda, \beta', \sigma^2)$, ϕ is the probability density function of the standard normal assumption and σ^2 is the variance of u_t. We can obtain the BC MLE is obtained by maximizing Let $\theta_0' = (\lambda_0, \beta_0', \sigma_0^2)$ be the true parameter value of θ. The BC MLE is generally inconsistent. However, if the error terms are i.i.d. random variables (hereafter, i.i.d. assumption) and the "small σ" assumption given by $\lambda_0\sigma_0/(1 + \lambda_0 x_t'\beta_0) \to 0$ (practically, $P[y_t < 0]$ is small enough under the normality assumption), the BC MLE can be a consistent estimator, and "small σ" asymptotics [15] of the BC MLE $\hat{\theta}_{BC}' = (\hat{\lambda}_{BC}, \hat{\beta}_{BC}', \hat{\sigma}_{BC}^2)$ are given by

$$\sqrt{T}(\hat{\theta}_{BC} - \theta_0) \to N\left[0, A^{-1}B(A')^{-1}\right], \tag{3}$$

where $A = -\dfrac{1}{T}E\left[\dfrac{\partial^2 \log L}{\partial\theta\partial\theta'}\bigg|_{\theta_0}\right]$, and $B = E\left[\dfrac{\partial \log f_t}{\partial\theta}\bigg|_{\theta_0} \dfrac{\partial \log f_t}{\partial\theta'}\bigg|_{\theta_0}\right]$.

2.2. N-Estimator

Nawata [16] considered the roots of the equations,

$$\begin{aligned} G_T(\theta) = \sum_t \Bigg[& -\frac{1}{\sigma^2\lambda}\left[\left\{\frac{\log(\lambda x_t'\beta + 1)}{\lambda} + \frac{z_t - x_t'\beta}{\lambda x_t'\beta + 1}\right\} y_t^{\lambda} - z_t\right](z_t - x_t'\beta) \\ & + \frac{1}{\lambda}\log(\lambda x_t'\beta + 1) + \frac{z - x_t'\beta}{\lambda x_t'\beta + 1}\Bigg] \equiv \sum_t g_t(\theta) \end{aligned} \tag{4}$$

$$\frac{\partial \log L}{\partial \beta} = 0, \text{ and } \frac{\partial \log L}{\partial \sigma^2} = 0.$$

When the first- and third-moments of u_t are zero, the estimator given by Equation (4) is consistent. The asymptotic distribution of the estimator $\hat{\theta}_N' = (\lambda_N, \beta_N', \sigma_N^2)$ (hereafter, N-estimator) becomes

$$\sqrt{T}(\hat{\theta}_N - \theta_0) \to N\left[0, C^{-1}D(C')^{-1}\right], \tag{5}$$

where $C = -E\left[\dfrac{\partial \ell_t(\theta)}{\partial\theta'}\bigg|_{\theta_0}\right]$, $D = E\left[\ell_t(\theta_0)\ell_t(\theta_0)'\right]$, $\ell_t(\theta)' = \left[g_t(\theta), \xi_t(\theta)', \varsigma_t(\theta)\right]$,

$\xi_t(\theta) = \dfrac{1}{\sigma^2}x_t(z_t - x_t'\beta)$, and $\varsigma_t(\theta) = \dfrac{(z_t - x_t'\beta) - \sigma^2}{2\sigma^2}$.

2.3. Hausman Test for the BC Model

The BC MLE is consistent under the i.i.d. and "small σ" assumptions. Therefore, we can test the null hypothesis consisting of these assumptions by the Hausman test using the N-estimator. Under the null hypothesis, we get,

$$\sqrt{T}\left(\hat{\lambda}_N - \hat{\lambda}_{BC}\right) \to N\left(0, \delta_1\right), \tag{6}$$

where $\delta_1 = (1,1)$ element of $\left(A^{-1} - C^{-1}\right) B \left(A^{-1} - C^{-1}\right)'$. Let $\hat{\delta}_1$ be the estimator of δ_1 and $t = \sqrt{T}\left(\hat{\lambda}_N - \hat{\lambda}_{BC}\right) \Big/ \sqrt{\hat{\delta}_1}$. Since $t \to N(0,1)$ under the null hypothesis, we can test using t as the test statistic [5]. Note that we cannot use two or more parameters in the Hausman test in this case [18]. We can use the BC MLE if the null hypothesis is accepted. Nawata and Kawabuchi [19] considered a further test when the null hypothesis is accepted. But the null hypothesis consists of compounded assumptions, and the further test is not necessary if the null hypothesis is accepted. Note that we need other estimators and tests if the null hypothesis is rejected [19]-[22].

3. Data and Summary of the Revisions for Cataract Surgeries

In this study, we use data from the Section of Health Care Economics of Tokyo Medical and Dental University. The data were collected from over 100 Japanese hospitals from July 2005 to March 2012. For each patient, gender, age, dates of hospitalization, medical payment amounts, DPC code, names of principle disease and disease that caused hospitalization, International Classification of Diseases 10th revision (ICD-10) code of the WHO for the diseases, up to four surgeries, information of comorbidities and complications, placement after hospitalization and other information of patients were available. Our original dataset contained information of 92,766 cataract patients and there were 56,364 one-eye cataract surgery cases. Although National Eye Institute [8] recommended to a 4 - 8 week interval between surgeries when a patient needs cataract surgeries for both eyes, both eyes are operated in a single hospitalization (hereafter, two-eye surgeries) to a large number of patients in Japan. 36.6% underwent two-eye surgeries in our dataset (For the rest of the patients, either DPC codes were not available or no surgeries were done).

As mentioned earlier, we analyzed patients who underwent one-eye cataract operations. The DPC codes, per diem payments by the LOS and Specific Hospitalization Periods for these patients are given in **Table 1**. (In Japan, medical payments are measured by points and 10 yen per point are paid to hospitals.) In all three revisions, three periods determined by the DPC/PDPS became shorter and per diem payments became less. There was a clear intention of the Japanese policy makers to reduce the LOS for cataract surgeries.

The dataset of 51,054 patients from 60 hospitals which had more than 300 cataract surgeries was used in the analysis. **Table 2** shows the average length of stay (ALOS) by hospital. The ALOS of all patients was 3.76 days

Table 1. DPC codes and inclusive payments for cataract patients+.

Periods	DPC Code	LOS and Per Diem Payments (points)				Specific Hospitalization Period (days)
2005-2006	0201103x01x000	LOS	1st-3rd	4th-6th	7th-10th	10
		Per Diem Payment	2509	1855	1577	
2006-2008	020110xx97x0x	LOS	1st-2nd	3rd-4th	5th-8th	8
		Per Diem Payment	2418	1787	1519	
2008-2010	020110xx97x0x0	LOS	1st	2nd-3rd	4th-7th	7
		Per Diem Payment	2363	1900	1615	
2010-2012	020110xx97xxx0	LOS	1st-2nd	3rd-4th	4th-6th	6
		Per Diem Payment	2237	1627	1464	

+: The DPC/PDPS is revised in April of every second year.

Table 2. Distribution of LOS by hospitals.

Hospital	No. of patients	LOS		Hospital	No. of patients	LOS	
		ALOS	S.D.			ALOS	S.D.
Hp1	684	4.14	1.31	Hp31	357	3.19	0.84
Hp2	493	2.39	0.95	Hp32	305	3.36	1.33
Hp3	383	6.20	1.90	Hp33	902	3.22	0.90
Hp4	658	5.16	1.21	Hp34	755	2.92	0.87
Hp5	969	3.30	1.35	Hp35	739	3.18	1.48
Hp6	448	3.44	0.96	Hp36	342	4.60	2.12
Hp7	684	3.47	1.22	Hp37	1719	4.09	1.47
Hp8	691	3.00	0.67	Hp38	642	6.17	1.49
Hp9	884	3.64	1.52	Hp39	1498	5.84	1.85
Hp10	496	2.99	0.13	Hp40	1534	3.12	1.56
Hp11	2442	2.85	0.83	Hp41	830	2.71	1.16
Hp12	436	3.43	1.88	Hp42	1342	4.61	1.82
Hp13	556	3.67	1.53	Hp43	2,877	3.45	1.41
Hp14	604	4.78	1.88	Hp44	1048	4.19	2.31
Hp15	570	2.13	0.59	Hp45	312	3.48	3.57
Hp16	1088	3.07	0.45	Hp46	592	4.05	2.35
Hp17	1251	3.31	0.83	Hp47	1145	3.89	0.97
Hp18	2124	4.00	0.26	Hp48	1539	4.25	1.91
Hp19	466	2.99	0.08	Hp49	1365	3.83	1.85
Hp20	560	2.07	0.47	Hp50	595	5.44	3.10
Hp21	1236	3.15	0.61	Hp51	355	3.08	0.65
Hp22	445	6.84	1.12	Hp52	719	4.39	1.55
Hp23	326	3.97	2.14	Hp53	1008	4.30	1.25
Hp24	893	3.08	0.74	Hp54	232	3.32	0.71
Hp25	703	4.04	0.56	Hp55	406	4.63	1.38
Hp26	1863	3.76	0.81	Hp56	363	6.66	2.35
Hp27	1632	3.55	1.04	Hp57	549	5.32	2.53
Hp28	744	3.05	0.41	Hp58	373	4.72	1.33
Hp29	683	3.46	0.64	Hp59	601	2.35	1.31
Hp30	355	3.35	0.93	Hp60	402	4.05	0.55
All	51,054	3.76	1.64				

with standard deviation (S.D.) of 1.64 days. The maximum and minimum ALOS among hospitals were 6.84 (Hp22) and 2.07 (Hp20) days, respectively. The difference was 4.77 days and there were large differences among hospitals. **Table 3** shows the total, inclusive and non-inclusive payments per patient to hospitals. The average total cost was 229,491 yen with S.D. of 45,602 yen, the average inclusive payment was 74,886 yen with S.D. of 36,209 yen, and the average non-inclusive payment was 154,606 yen with S.D. of 22,578 yen. The non-inclusive payment composed of about two-thirds and inclusive cost was just one third. However, S.D. of inclusive payments is much bigger than that of the non-inclusive payments, and a large portion of the difference of

Table 3. Distribution of medical payments per patient by hospitals (yen).

Hospital	Total	Inclusive	Non-inclusive	Hospital	Total	Inclusive	Non-inclusive
HP1	242,199	83,748	158,451	HP31	221,323	63,981	157,341
HP2	204,729	50,934	153,795	HP32	222,677	64,084	158,593
HP3	275,758	115,179	160,579	HP33	223,553	62,508	161,045
HP4	262,723	99,871	162,851	HP34	208,510	63,358	145,152
HP5	219,202	67,852	151,350	HP35	212,968	60,918	152,049
HP6	229,684	69,486	160,198	HP36	243,604	82,411	161,193
HP7	226,709	70,517	156,192	HP37	240,610	81,521	159,089
HP8	216,297	61,282	155,015	HP38	273,376	115,719	157,657
HP9	220,770	63,162	157,608	HP39	272,105	112,470	159,635
HP10	220,308	68,075	152,234	HP40	222,369	65,550	156,819
HP11	216,198	60,095	156,103	HP41	201,569	56,355	145,214
HP12	236,829	72,106	164,723	HP42	246,145	89,179	156,966
HP13	228,235	78,297	149,937	HP43	221,168	68,954	152,214
HP14	248,177	96,540	151,637	HP44	213,577	63,491	150,086
HP15	196,332	46,225	150,107	HP45	241,764	80,912	160,852
HP16	215,142	63,749	151,393	HP46	225,939	73,496	152,443
HP17	226,144	73,160	152,984	HP47	244,372	82,581	161,792
HP18	219,451	73,708	145,743	HP48	227,587	75,657	151,930
HP19	217,456	62,814	154,642	HP49	231,591	80,034	151,556
HP20	200,137	45,448	154,688	HP50	226,552	76,105	150,447
HP21	218,871	65,303	153,568	HP51	278,392	108,986	169,406
HP22	284,528	127,994	156,534	HP52	220,903	64,592	156,311
HP23	237,239	81,536	155,702	HP53	241,561	79,298	162,263
HP24	216,553	63,829	152,724	HP54	246,518	84,819	161,700
HP25	229,000	78,978	150,022	HP55	249,042	90,844	158,198
HP26	231,262	76,243	155,018	HP56	287,360	129,554	157,805
HP27	231,262	76,243	155,018	HP57	250,477	95,791	154,686
HP28	220,438	62,688	157,750	HP58	238,497	82,588	155,909
HP29	220,863	68,050	152,812	HP59	194,205	50,433	143,772
HP30	221,134	68,856	152,278	HP60	229,125	79,575	149,550
All	229,491	74,886	154,606				

the medical payments caused by the inclusive payments. The maximum total, inclusive and non-inclusive payments among hospitals were 287,360 (Hp56), 129,554 (Hp56) and 164,406 (Hp51) yen, respectively. The minimum total, inclusive and non-inclusive payments among hospitals were 194,205 (Hp59), 45,448 (Hp20) and 143,772 (Hp59) yen, respectively. The differences were 93,155, 84,106 and 25,634 yen, respectively. The differences of the inclusive payments among hospitals were much larger than those of the non-inclusive payments.

4. Results of Estimation

4.1. Analysis of the LOS by the BC Mode

Figure 1 shows the distribution of LOS of one-eye cataract surgeries. Since the distribution has a fat tail on the

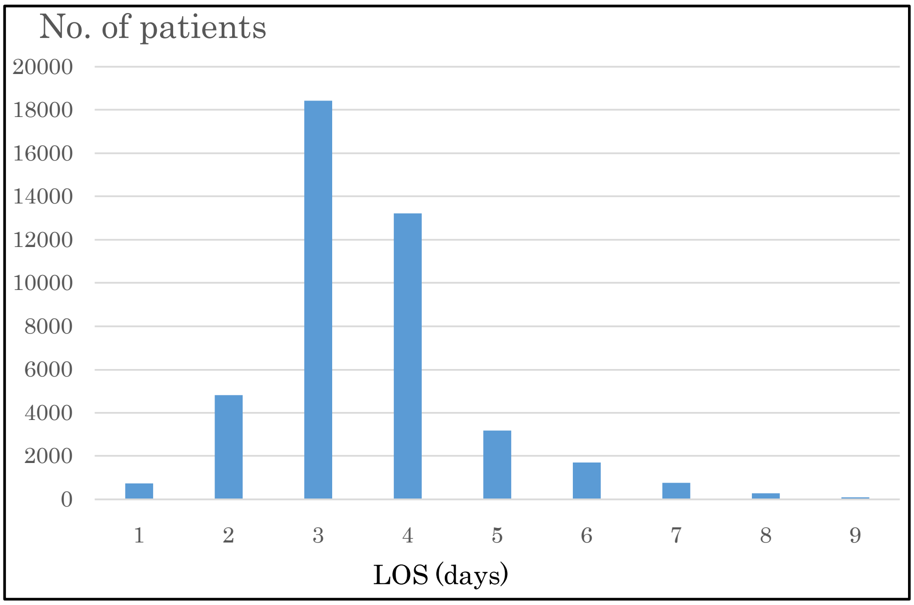

Figure 1. Distribution of the LOS.

right side, we use the BC model described in Section 3. For the analysis of LOS, it is necessary to consider the characteristics of the patients and the types of principal diseases. We also consider the effects of advances and improvements of cataract surgery technologies. The explanatory variables used in the BC model were shown in **Table 4**. As the basic information of patients, gender and age were considered. Under the Japanese mandatory public insurance system, the direct payments of patients was 10% for age 70 or over and 30% for younger than 70 in the sample period. So, the Over 70 dummy was added. Comorbidity (number of comorbidities), Complication (number of complications), and Emergency, Outpatient and Home dummies were used for representing conditions of patients. The Summer and Winter dummies were used to evaluate seasonal effects. To evaluate the effects of three revisions of the DPC/PDS, which is one the major purposes of the paper, we used three (*i.e.*, After 2006, 2008 and 2010) dummies. For evaluation of advances of medical technology for cataract surgeries, Trend was added. Since we are analyzing a long term effect (7 years), the trend might have been changed and we added the squared term of trend. The payment goes back to the conventional fee-for-service base if the LOS exceeds the Specific Hospitalization Period, and per-diem payment is not reduced after the Specific Hospitalization Period. Over Period dummy was used to evaluate this effects. Thirteen ICD-10 dummies (base of these dummies was H25.0), were used to represent the influences of principal diseases. We used sixty hospital dummies were used to evaluate the influences of the hospital directly and a constant term was not included in the model

As a result, $x_{ij}'\beta$ of Equation (1) became

$$\begin{aligned} x_{ij}'\beta = {} & \beta_1\text{Female} + \beta_2\text{Age} + \beta_3\text{Over 70} + \beta_4\text{Comorbidity} + \beta_5\text{Complication} \\ & + \beta_6\text{Emergency} + \beta_7\text{Outpatient} + \beta_8\text{Home} + \beta_9\text{Summer} + \beta_{10}\text{Winter} \\ & + \beta_{11}\text{After 2006} + \beta_{12}\text{After 2008} + \beta_{13}\text{After 2010} + \beta_{14}\text{Trend} + \beta_{15}\left(\text{trend}\right)^2 \\ & + \beta_{16}\text{Over Period} + \sum \beta_j \; j\text{-th ICD 10 dummy} + \sum \beta_k \text{ Hp } k \text{ dummy.} \end{aligned} \tag{7}$$

The result of the estimation is given in **Table 5**. The estimates of the transformation parameters were $\hat{\lambda}_{BC} = 0.2489$ and $\hat{\lambda}_N = 0.2402$. The estimate of $\sqrt{V\left(\hat{\lambda}_{BC} - \hat{\lambda}_N\right)} = 0.0129$ and we got $t = 0.6733$. Therefore, the i.i.d. and "small σ" assumptions were accepted at the 5% significance level and we can use the BC MLE in this analysis.

The estimate of Female dummy and Age were positive and significant at 1% level. Although the estimate of Over 70 were positive but not significant at the 5%. The LOS became longer for females and for older patients, but we did not admit the effect of lower payments for patients age 70 or over in this study. The estimates of

Table 4. Definitions and summary of explanatory variables.

Variable	Definition	Summary of 51054 patients
Female	Dummy variable; 1: female, 0: otherwise	1: 28,745
Age	Age of patient	mean: 73.4, S.D.: 10.2
Over 70	Dummy variable; 1: Age 70 or over, 0: otherwise	1: 36,293
Comorbidity	Number of comorbidities,	0: 2814, 1: 11,938, 2: 5220, 3: 2724, 4: 3068
Complication	Number of complications	0: 33,993, 1: 10,992, 2: 5087 3: 772; 4: 210
Emergency	Dummy variable; 1: Emergency hospitalization, 0: otherwise	1: 9021
Outpatient	Dummy variable; 1: Outpatient, 0: otherwise	1: 48,267
Home	Dummy variable; 1: return to home, 0: otherwise	1: 46,003
Summer	Dummy variable; 1: summer+, 0: otherwise	1: 12,532
Winter	Dummy variable; 1: winter++, 0: otherwise	1: 10,147
After 2006	Dummy variable; 1: After April 2006. 0: otherwise	1: 50,006
After 2008	Dummy variable; 1: After April 2008, 0: otherwise	1: 41,656
After 2010	Dummy variable; 1: After April 2010, 0: otherwise	1: 23,005
Trend	No. of months from April 2005	months from April 2005
Over Period	Dummy variable; 1: LOS exceeds the Specification Hospitalization Period, 0: otherwise	1: 1098
ICD 10 dummies		
H250+++	senile incipient cataract	24,022 patients
H251	1: senile nuclear cataract, 0 otherwise	1: 7672
H252	1: senile cataract, morgagnian-type, 0 other wise	1: 535
H258	1: other senile cataract, 0: otherwise	1: 2395
H259	1: senile cataract, unspecified, 0: other wise	1: 5398
H260	1: infantile and juvenile cataract, 0: otherwise	1: 2828
H262	1: complicated cataract, 0: otherwise	1: 161
H263	1: drug-induced cataract, 0: otherwise	1: 119
H264	1: After-cataract, 0: otherwise	1: 50
H268	1: other specified cataract, 0: otherwise	1: 520
H269	1: unspecified cataract, 0 otherwise	1: 5938
H27	1: Other disorders of lens (H271 & H272), 0: otherwise	1: 171
H28	1: diabetic cataract (H281 & H282), 0: otherwise	1: 733
Hospital Dummies		
Hp i	1: Hospital i; 0: otherwise	

+Summer: July and August, ++Winter: December to February, +++: base of ICD10 dummies.

Comorbidity and Complication were positive and significant at the 1% and 5% levels, and comorbidities and complications made LOS longer as expected. Although the estimate of Emergency dummy was not significant, estimates of Outpatient and Home dummies were negative, positive and significant at the 1% level. It is reasonable the LOS becomes shorter if a patient is an outpatient before hospitalization since the hospital is be able to

Table 5. Results of estimation of the BC model for LOS by the BC MLE.

Variable	Coefficient	Std. Error	t-Statistic	Variable	Coefficient	Std. Error	t-Statistic
lambda	0.2489	0.0011	224.03**	HP16	1.4905	0.0288	51.71**
Female	0.0164	0.0029	5.5810**	HP17	1.5679	0.0292	53.76**
Age	0.001512	0.000239	6.3264**	HP18	1.7921	0.0284	63.12**
Over 70	0.0100	0.0052	1.9381	HP19	1.4739	0.0283	52.02**
Comorbidity	0.0132	0.0016	8.3719**	HP20	1.0074	0.0299	33.74**
Complication	0.0067	0.0033	2.0168*	HP21	1.4409	0.0295	48.77**
Emergency	0.0102	0.0169	0.6032	HP22	2.1867	0.0358	61.01**
Outpatient	−0.0265	0.0081	−3.2594**	HP23	1.7407	0.0347	50.23**
Home	0.0100	0.0036	2.7644**	HP24	1.4356	0.0290	49.43**
Winter	−0.0058	0.0038	−1.5223	HP25	1.8517	0.0285	64.91**
Summer	−0.0027	0.0036	−0.7374	HP26	1.7214	0.0288	59.77**
After 2006	−0.0012	0.0246	−0.0484	HP27	1.6169	0.0283	57.06**
After 2008	−0.0527	0.0190	−2.7821**	HP28	1.4743	0.0292	50.51**
After 2010	−0.0023	0.0065	−0.3504	HP29	1.6666	0.0296	56.27**
Trend	−0.00708	0.00094	−7.5117**	HP30	1.5463	0.0320	48.39**
$(\text{Trend})^2$	0.0000312	0.0000083	3.7772**	HP31	1.4814	0.0337	43.97**
Over Period	1.2167	0.0211	57.64**	HP32	1.5116	0.0335	45.09**
H251	−0.0267	0.0068	−3.9450**	HP33	1.4857	0.0295	50.41**
H252	0.1085	0.0169	6.4203**	HP34	1.3523	0.0311	43.42**
H258	0.0933	0.0091	10.21**	HP35	1.4227	0.0388	36.71**
H259	−0.0191	0.0069	−2.7890**	HP36	1.7679	0.0363	48.73**
H260	0.0196	0.0065	3.0307**	HP37	1.7921	0.0297	60.35**
H262	0.0737	0.0268	2.7514**	HP38	2.2936	0.0316	72.61**
H263	−0.0367	0.0335	−1.0954	HP39	2.2464	0.0289	77.67**
H264	−0.1568	0.0639	−2.4523*	HP40	1.3932	0.0327	42.64**
H268	−0.1109	0.0285	−3.8909**	HP41	1.2781	0.0338	37.86**
H269	−0.0355	0.0062	−5.6832**	HP42	1.9097	0.0301	63.39**
H270	0.3908	0.0464	8.4212**	HP43	1.6331	0.0295	55.31**
H280	0.0609	0.0105	5.8055**	HP44	1.4403	0.0308	46.74**
Hospital Dummies				HP45	1.8060	0.0288	62.78**
HP1	1.8032	0.0314	57.39**	HP46	1.5486	0.0350	44.27**
HP2	1.1513	0.0312	36.93**	HP47	1.7011	0.0327	52.01**
HP3	2.3402	0.0323	72.53**	HP48	1.7760	0.0298	59.53**
HP4	2.0914	0.0294	71.13**	HP49	1.7809	0.0301	59.12**
HP5	1.4971	0.0291	51.42**	HP50	1.7393	0.0289	60.09**

Continued

HP6	1.6357	0.0300	54.55**	HP51	2.1588	0.0399	54.05**
HP7	1.5352	0.0330	46.54**	HP52	1.4731	0.0294	50.17**
HP8	1.4289	0.0295	48.47**	HP53	1.8671	0.0304	61.33**
HP9	1.6613	0.0313	53.11**	HP54	1.9114	0.0296	64.50**
HP10	1.3586	0.0256	53.11**	HP55	1.9970	0.0312	64.05**
HP11	1.3568	0.0288	47.03**	HP56	2.2977	0.0349	65.86**
HP12	1.3758	0.0444	30.99**	HP57	2.0826	0.0331	62.94**
HP13	1.5123	0.0334	45.34**	HP58	1.9887	0.0302	65.80**
HP14	1.9567	0.0292	66.90**	HP59	1.0367	0.0367	28.26**
HP15	1.0654	0.0271	39.27**	HP60	1.8200	0.0299	60.91**

: Significant at the 1% level, *:Significant at the 5% level, R2 = 0.5686. Definitions and summaries of variables are given in **Table 4.

conduct various medical checkups in advance. The result of Home dummy implied that LOS becomes shorter if patients discharged to the place other than their home, and a problem of "social hospitalization" (a patient stays at hospital without medical treatments because there is no place to go after hospitalization, for details, see Innami [23]) did not occur in cataract surgeries. Both estimates of Winter and Summer dummies were not significant at the 5% level, and the seasonal effects were not admitted. Among three dummies which evaluated effects of the revisions, that is one of the major subjects of this study, only the estimate of the 2008 dummy was significant at the 1% level and the other two were not significant. In the 2008 revision, the Period I, the period hospitals get largest payments, was shorten to just one day. On the other hand, the Period I was extended to two days in 2010 revision. So, this might be an important factor affected the behavior of hospitals. As previously mentioned, many patients prefer shorter LOS. Therefore, shortening LOS not only reduces the medical payments but also becomes patients' benefits. The estimates of Trend and $(\text{Trend})^2$ were significant at the 1% level and their signs were positive and negative. This means that was the LOS became shorter but effects becomes smaller as time went. The estimate of Over Period dummy was 1.217 and its t-value was 57.648. This means the effects of the Specific Period was much larger than those of other explanatory variables. For the ICD-10 dummies, estimates of H251, H259, H268 and H269 were negative and significant at 1% level. H264 was negative and significant at 5% level. On the other hand, H252, H258, H262, H27 and H28 were positive and significant at 1% level. These types of diseases affected LOS. H263 was not significant and we did not admit the effect of this type of disease.

For the estimates of the Hospital dummies, the maximum was 2.332 (Hp56) and the minimum was 1.108 (Hp5); the difference was 1.305 and was much bigger than the estimates of most of other explanatory variables. This indicated that there remained large differences among hospitals, even after eliminating the influences of variables including patient characteristics, disease types, three revisions of the DPC/PDPS, time trend, and Specific Hospitalization Period.

4.2. Analysis of Non-Inclusive Payments

For the analysis of non-inclusive payments per patient, n_p_t, we used the ordinary least squares method. The explanatory variables are the same as the previous case and the model is given by

$$\begin{aligned} n\_p_t = {} & \beta_1\text{Female} + \beta_2\text{Age} + \beta_3\text{Over 70} + \beta_4\text{Comorbidity} + \beta_5\text{Complication} \\ & + \beta_6\text{Emergency} + \beta_7\text{Outpatient} + \beta_8\text{Home} + \beta_9\text{Summer} + \beta_{10}\text{Winter} \\ & + \beta_{11}\text{After 2006} + \beta_{12}\text{After 2008} + \beta_{13}\text{After 2010} + \beta_{14}\text{Trend} + \beta_{15}(\text{trend})^2 \\ & + \beta_{16}\text{Over Period} + \sum \beta_j \ j\text{-th ICD 10 dummy} + \sum \beta_k \ \text{Hp } k \text{ dummy}. \end{aligned} \tag{8}$$

We cloud not get the payment information for some patients and the dataset of 50,234 patients was used in the analysis. The results of estimation are given in **Table 6**. The estimate of Female dummy not significant at 5%

Table 6. Results of estimation of the non-inclusive payment model.

Variable	Coefficient	Std. Error	t-Statistic	Variable	Coefficient	Std. Error	t-Statistic
Female	−37	184	−0.2011	HP17	172,703	1695	101.91**
Age	−47	14	−3.2945**	HP18	162,774	1628	99.96**
Over 70	117	314	0.3732	HP19	175,841	1838	95.65**
Comorbidity	1775	99	17.98**	HP20	168,974	1794	94.19**
Complication	3023	198	15.26**	HP21	164,883	1729	95.34**
Emergency	7081	864	8.1938**	HP22	167,219	1860	89.92**
Outpatient	−1734	415	−4.1765**	HP23	174,462	1942	89.86**
Home	−1944	372	−5.2212**	HP24	166,060	1761	94.32**
Summer	−126	226	−0.5569	HP25	170,493	1762	96.74**
Winter	106	239	0.4448	HP26	172,670	1650	104.62**
After 2006	−18,467	1383	−13.35**	HP27	169,874	1658	102.45**
After 2008	5708	1003	5.6938**	HP28	175,816	1781	98.69**
After 2010	−427	419	−1.0193	HP29	171,458	1778	96.43**
Trend	−82	52	−1.5562	HP30	163,053	1861	87.64**
$(\text{Trend})^2$	0.819	0.466	1.7556	HP31	173,870	1762	98.69**
Over Period	24,342	672	36.21**	HP32	174,103	1957	88.97**
H251	248	378	0.6573	HP33	178,968	1706	104.90**
H252	9242	906	10.20**	HP34	161,768	1788	90.48**
H258	3911	547	7.1551**	HP35	161,247	1779	90.66**
H259	1158	401	2.8865**	HP36	167,078	1938	86.22**
H260	−472	467	−1.0099	HP37	172,139	1629	105.69**
H262	1093	1667	0.6554	HP38	170,436	1860	91.61**
H263	925	1881	0.4920	HP39	175,254	1583	110.71**
H264	−55,152	2905	−18.98**	HP40	176,169	1625	108.44**
H268	−757	1566	−0.4834	HP41	164,822	1762	93.55**
H269	1514	399	3.7912**	HP42	174,530	1661	105.06**
H27	110,127	1625	67.78**	HP43	172,022	1660	103.65**
H28	−2543	801	−3.1739**	HP44	168,195	1843	91.25**
Hospital Dummies				HP45	179,032	1629	109.9298**
HP1	171,504	1747	98.17**	HP46	168,452	1959	85.99**
HP2	172,735	1838	93.96**	HP47	177,219	1792	98.89**
HP3	174,309	1867	93.33**	HP48	165,980	1707	97.21**
HP4	175,869	1779	98.83**	HP49	170,322	1588	107.28**
HP5	169,654	1689	100.39**	HP50	167,846	1667	100.69**
HP6	179,096	1876	95.43**	HP51	183,413	2198	83.46**

Continued

HP7	173,722	1809	95.99**	HP52	168,072	1958	85.85**
HP8	169,557	1749	96.93**	HP53	176,902	1741	101.63**
HP9	175,138	1713	102.21**	HP54	179,135	1724	103.91**
HP10	169,494	1694	100.04**	HP55	173,405	1912	90.68**
HP11	174,903	1644	106.33**	HP56	168,902	1925	87.76**
HP12	182,740	1842	99.17**	HP57	170,543	1827	93.35**
HP13	167,591	1860	90.07**	HP58	173,988	1,862	93.43**
HP14	165,899	1747	94.94**	HP59	163,938	1,788	91.68**
HP15	169,137	1757	96.23**	HP60	160,853	1,913	84.10**
HP16	166,004	1718	96.60**	R2		0.1969	

: Significant at the 1% level, *:Significant at the 5% level. Definitions and summaries of variables are given in **Table 4.

level. Although the estimate of Age was negative and significant, Over 70 was not significant at the 5%. The non-inclusive payment became smaller for older patients, but we did not admit the effect of lower payments for patients age 70 or over in this study. The estimates of Comorbidity and Complication were positive and significant at the 1% level, and comorbidities and complications made non-inclusive payments higher. Although the estimates of Emergency and Outpatient dummies were not significant, estimates of Outpatient and Home dummies were at the 1% level. Emergency hospitalization increased the non-inclusive payments, but a patient was an outpatient or returning home reduced the non-inclusive payments. Both estimates of Winter and Summer dummies were not significant at the 1% level, and the seasonal effects were not admitted. Among three dummies which evaluated effects of the revisions, the estimates of the 2006 and 2008 dummies were significant at the 1% level but the signs were opposite. The 2006 revision made the non-inclusive payment lower and 2008 revision made it higher. The estimates of Trend and $(\text{Trend})^2$ were not significant and we could not find time trends unlike the LOS case. The estimate of Over Period dummy was 24,342 and its t-value was 36.218. This means that the LOS exceeded the Specific Period Hospitalization, not only LOS but also non-inclusive payments increased by a large amount. For ICD-10 dummies, estimates of H252, H258, H259, H269 and H27 were positive and significant at 1% level. Especially, the estimate of H27 was 110,127 yen and very high. This was caused by the fact there were many patients who received surgeries of vitreous bodies with cataract surgeries. On the other hand, the estimate of H264 and H28 were negative and significant at 1% level. The value of H264 was 55,152 yen. H264 is after-cataract; that is a patient took a cataract surgery before and lens capsule becomes dirty again, and the surgery just makes the lens capsule clean. The payments for this surgery was lower than regular cataract surgeries.

For the estimates of the Hospital dummies, the maximum was 183,412 (Hp44) yen and the minimum was 160,853 yen (Hp5); the difference was 22,559 yen or 14.6% of the average non-exclusive payments. The difference was much smaller than that of the LOS.

5. Discussion

We found that the differences of LOS among hospitals were very large but differences of the non-inclusive payments (mainly payments related to surgeries) were relatively small. Although the types of diseases were different, we got the similar results for diabetes [19] [21]. Another question is whether the LOS and the non-inclusive payments were related or not. The correlation coefficient of the estimates of hospital dummies between the LOS and non-inclusive payment models was 0.224 and t-value for testing no correlation is 1.798. We could not say that the LOS and the non-inclusive pay were correlated. By the three revisions, the periods determined by the DPC/PDPS were shortened and per diem payments were reduced. This means that there was a strong political implication to reduce the LOS to control the medical payments. Among three revisions, only one revision significantly reduced the LOS. The results of this study shows that the LOS did not decrease much. However, the LOS could be reduced by the efforts of hospitals. For example, Kobato *et al*. [24] reported that the LOS was reduced by introduction of proper clinical pathways.

More recently, the Ministry of Health, Labour and Welfare [25] released the Japanese medical payments reached 40 trillion yen in fiscal year 2014 (Japanese fiscal year is from April to March), this figure is expected to increase as aging the population in the future. The medical payment has become a big financial problem. As already pointed out by Nawata and Kawabuchi [21], the best answers for this problem is to treat patients more efficiently and control payments without degradation of treatments. There were large differences in ALOS among hospitals even after eliminating effects of various factors. This suggested that it might be possible for many hospitals to reduce the LOS without degradation of treatments for cataract surgeries.

In the revision of the medical payment system implemented April 2014 [26], the cataract surgery is classified under the category of the Short Stay Operation Basic Payment 3. If a hospital and a patient satisfy the required conditions, a hospital gets the same amount of payments. In cataract surgeries with lens insertion, a hospital get 270,930 yen if the LOS is 5 days or less. It is essentially same as the DRG/PPS (Diagnosis-Related Group/ Prospective Payment System) widely used in the United States and other countries[1)]. The numbers of diseases, hospitals and patients under this system are currently small, it will be expected to increase in the future. Therefore, evaluation of the new (DRG/PPS type) payment system is an important subject for the financial sustainability of the Japanese medical payment system.

6. Conclusions

In this paper, we conducted a long term survey of the cataract surgeries. The sample period was about 7 years, from July 2005 to March 2012. We evaluated the effects of three revisions of the medical payment system that were done in 2006, 2008 and 2010. About one million surgeries are performed in Japan annually. For the analysis, the Box-Cox transformation model and Hausman test using Nawata's estimator are used for the LOS, and the ordinary least squares method is used for the non-inclusive payments. To evaluate these changes, we analyzed a dataset of 51,054 patients obtained from 60 hospitals (Hp1-60) where surgeries more than 300 one-eye cataract surgeries were performed during the period. The time trend reduced the LOS but degrees of reduction became smaller.

For the analysis of the LOS, gender, age, numbers of comorbidities and complications, outpatient before hospitalization, and place to go back after hospitalization were significant variables. The time trend and squared of trend were significant and the LOS became shorter but effects became smaller as time went. For ICD-10 dummies, H264 and H28 were negative and significant. H252, H258, H262 and H27 were positive and significant. The Specific Hospitalization Period also strongly affected the non-inclusive payments. Among three dummies which evaluated effects of the revisions, only the estimate of the 2008 dummy was significant and the 2008 revision reduced the LOS but not the other two. There were large differences among estimates of the hospital dummies, indicating that there remained large differences among hospitals, even after eliminating the influences of various factors.

For the analysis of the non-exclusive payments, gender, numbers of comorbidities and complications, being an outpatient before hospitalization, place to go back after hospitalization, emergency were significant variables. The effects of time trend was not admitted in this case. For ICD-10 dummies, H252, H258, H259, H264, H269, H27 and H28 were significant variables. As the LOS case, the Specific Hospitalization Period also strongly affected the non-inclusive payment. For the effects of the revisions, 2006 and 2008 dummies were significant but the signs were opposite. The 2006 revision made the non-inclusive payment lower but 2008 revision made it higher. For the estimates of the Hospital dummies, the largest difference was 22,559 yen or 14.6% of the average non-exclusive payments. The difference was much smaller than that of the LOS.

In this study, we analyzed the LOS and medical payments for cataract surgeries. For financial sustainability of the Japanese medical system, it is necessary to evaluate other diseases. Evaluation of the Short Stay Operation Basic Payment system expanded in 2014 is also necessary. In this paper, characteristics of hospitals were not analyzed. Barbieri *et al*. [27] reported that the LOS of private hospitals was shorter than that of public ones. These are subjects to be studied in the future.

Note: 1) Although 10 hospitals (8 national and 2 social insurance hospitals) had adopted the DRG/PPS on a trial basis from 1998 to 2004, it was not accepted by the Japanese medical society.

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