An analysis of the length of hospital stay for type 2 diabetes patients in Japan by the Box-Cox transformation model

Nawata, K. and K. Kawabuchi
Curriculum Vitae

• Name: (Family) Nawata, (First) Kazumitsu
• Nationality: Japanese
• Professor, Graduate School of Engineering, University of Tokyo
• Visiting Department of Economics & Related Studies, University of York, from April 2016 to Sept. 2016
• Education:
  1979 B. Eng., Faculty of Engineering, University of Tokyo

  1986 Ph.D., Department of Economics, Stanford University
• Job Experiences:
• 1986-1989  Assistant Professor, Department of Economics, University of Chicago
• 1989-1999  Associate Professor, University of Tokyo
• 1990 - present  Professor, University of Tokyo
• Figure 1 shows the Japanese medical expenditures from 1985 to 2013 (Ministry of Health, Labour and Welfare, 2014a). The Japanese total medical expenditures have been constantly increasing on the order of 3% per year.
As a result, the Japanese medical expenditures reached 40 trillion yen in FY 2013 and increased by 0.85 trillion yen from the previous FY. Since Japanese nominal GDP did not increase over the last 20 years, the medical expenditure reached 8.3% of the GDP.
• Figure 1. Japanese medical expenditures
• According to the World Health Organization (WHO, 2015), the total health expenditures were

• 9.4% of GDP in Australia, 10.9% in Canada, 11.6% in France, 11.3% in Germany, 10.3% in Japan, 9.3% in the United Kingdom, and 17.0% in the United States in 2012.

• The Japanese figure was thus not particularly large among major countries at this time.
Figure 2. Distribution of Japanese population by age
• Figure 2 shows the Japanese population structure by age in 2013. The portion of the aged population is expected to increase in the future.

• The medical expenditure per person in FY 2012 was:
  • younger than 65: 177 thousand yen;
  • 65 or older: 717 thousand yen;
  • 70 or older: 805 thousand yen;
  • and 75 or older: 892 thousand yen
Japan instituted a mandatory public health insurance system, and since that time all Japanese have been required to join some type of public insurance. Currently, the medical expenditures paid by patients are:

- 30% of their actual expenditures for individuals younger than 70.
- 20% of expenditures for those aged 70 - 74 (10% by April 2014)
- 10% of expenditures for those age 75 or older
• Monthly limits have been set for patients 70 or older: 12 thousand yen for outpatient services and 44.4 thousand yen for overall medical payments.

• As a result, the public expenditures and the total cost of health insurance premiums have reached 15.146 trillion and 19.120 trillion yen.

• Direct payments by patients accounted for only 4.619 trillion yen or **11.9%** of total medical expenditures in FY 2012.
• Hence the financial sustainability of the system is now a very serious question.
• There is no doubt that the Japanese medical expenditure will increase rapidly in the future unless fundamental improvements are made to the medical system.
• One of the best answers for the financial problem is to treat patients more efficiently and control expenditures without degradation of treatments.

Longer length of hospital stay (LOS) is one of the most prominent characteristics of the Japanese medical system.
• According to OECD, the average lengths of stay (ALOS) for all causes in 2011 were 5.8 days in Australia, 7.4 days in Canada, 5.6 days in France, 9.3 days in Germany, 7.7 days in Italy, 7 days in the United Kingdom, and 4.8 days in the United States (the US figure was for 2010).

• In Japan, however, the ALOS of hospitals was 32.0 days for all beds and 17.9 days for general beds; clearly these durations were much longer than those of other major countries, which affected medical expenditures. Hence it might be possible to control the medical expenditures by reducing LOS.
• Diabetes has become a very important disease both in medical and economic terms. The Japanese medical expenditure on diabetes in 2013 was 1.21 trillion yen; diabetes was thus the one of the most costly disease.
Moreover, diabetes can cause serious complications such as vision loss, kidney disease (nephropathy), heart failure, and stroke [4][5]. If the costs of taking care of the comorbidities and complications of diabetes were included, the medical costs of diabetes would likely be much higher. The Public Health Agency of Canada [6] has reported that the “direct health care costs may be as much as 4.5 times higher than when looking at diabetes alone.”
• In the United States, the total cost of diagnosed diabetes was estimated at $245 billion in 2012 according to American Diabetes Association (ADA).

• According to the OECD, the annual cost of diabetes prevention and treatment is approximately 90 billion euro in Europe alone.

• The International Diabetes Federation (IDF) reported that the number of people with diabetes was 387 million in 2014, or 8.3% of the world population, and was expected to increase by 205 million in 2035.
• In Japan, the potential population with diabetes age 20 or over was estimated as 16.2% and 9.2% of the male and female population in 2013.
Moreover, Kudo et al. (2011) and Inoue et al. (2006) have pointed out that having diabetes as a comorbidity prolonged LOS, and the true cost of diabetes may be higher than the above number.

A large part of the medical cost of diabetic patients is determined by LOS. However, LOS for diabetic patients has not been widely studied, and only few studies have been done in Japan.
• According to the IDF, among all diabetes cases, 90% or more are type 2 diabetes.
• Although insulin is not produced in type 1 diabetes, the body does not use insulin properly in type 2 diabetes.
• The pancreas makes extra insulin at first, but it will eventually be unable to make enough insulin to keep the blood glucose levels normal.

• When glucose builds up in the blood, it can cause:
  i) cells may be starved for energy immediately, and
  ii) high blood glucose levels may hurt eyes, kidneys, nerves or hearts in a long time.
Treatments of type 2 diabetes are lifestyle improvements, oral pills and insulin injections (ADA). The ADA stated that “Stay at a healthy weight, eat well and be active. With these steps, you can stay healthier longer and lower your risk of diabetes” (ADA), and the risk of type 2 diabetes can be controlled and reduced.
• In this paper, we analyze LOS of type 2 diabetes patients by the Box-Cox transformation model (BC model), taking account for the different variances among hospitals.

• The maximum likelihood estimator (BC MLE), which maximizes the likelihood function under the normality assumption, is used for the estimation of the BC model.
• However, Showalter (1994) reported large biases of the BC MLE when heterogeneity exists in variances.

• For LOS in particular, variances often differ greatly among hospitals, even after controlling for the characteristics of diseases, treatments and patients. We propose a new estimator that functions well even under heteroscedasticity.
Following the recommendations of a report submitted by the Central Social Insurance Medical Council concerning the 2002 revision of the Medical Service Fee Schedule, a new case-mix payment was introduced in 82 special functioning hospitals in Japan in April 2003.
• Since April 2004, the system has been gradually extended to general hospitals that satisfy certain prerequisites.

• The payment system is called DPC/PDPS (Diagnosis Procedure Combination/ Per Diem Payment System)
• As of April 2014, a total of 1,585 hospitals had joined the DPC system and an additional 278 hospitals were preparing to join the DPS/PDPS (hereafter DPC hospitals).

• The DPC hospitals comprise about 25% of the 7,483 general hospitals in Japan. The DPC hospitals have 511,439 beds (474,981 beds for already-joined hospitals and 36,458 for preparing-to-join hospitals), which represents 57% of the total number of beds (897,749 beds) in all general hospitals.
The basic per diem payment is reduced as the LOS becomes longer.
The DPC hospitals are required to computerize their medical information, which makes it possible for us to use large-scale data sets.
• Next, we analyzed the LOS of regular patients without any operations by the proposed methods.

• We used the DPC dataset of 12,666 patients with DPC code 10070xxxxx0x collected from 60 DPC hospitals in Japan.

• We then evaluated the daily expenditures by the ordinary least squares (OLS) method.
• The Box-Cox (1964) transformation model (BC model) is used in this analysis
An Analysis of Transformations

By G. E. P. Box and D. R. Cox

University of Wisconsin Birkbeck College, University of London

[Read at a Research Methods Meeting of the Society, April 8th, 1964, Professor D. V. Lindley in the Chair]

Summary
In the analysis of data it is often assumed that observations $y_1, y_2, ..., y_n$ are independently normally distributed with constant variance and with expectations specified by a model linear in a set of parameters $\theta$. In this paper we make the less restrictive assumption that such a normal, homo-
• For the estimation of the model, the maximum likelihood estimator (BC MLE) is usually used. However, two conditions must be satisfied in order for the BC MLE to become a consistent estimator.

• However, two conditions must be satisfied in order for the BC MLE to become a consistent estimator. These are:

• i) the “small $\sigma$” condition described in Bickel and Doksum (1981), and Nawata and Kawabuchi (2014); and

• ii) the error terms must be independent and identically distributed (i.i.d.) random variables.
BC model and BC MLE.

Suppose that the LOS of the patient $j$ in the hospital $i$ is given by the BC model:

$$y_{ij} = \begin{cases} (t_{ij}^λ - 1)/λ_i & \text{if } λ_i \neq 0, \\ \log(t_{ij}) & \text{if } λ_i = 0 \end{cases}$$  \hspace{1cm} (1)$$

$$y_{ij} = x_{ij}'β + u_{ij} \quad i = 1,2,...,k, \quad j = 1,2,...,n_i$$

where $t_{ij}$ is LOS, $λ$ is the transformation parameter, and $β$ are the $k$-th dimensional vectors of the explanatory variables and coefficients, $k$ is the number of hospitals, $n_i$ is the number of patients in hospital $i$, and $n = \sum_i n_i$ respectively.
\( u_{ij} \) is assumed to follow the normal distribution with mean 0 and variance \( \sigma_i^2 \). Let \( \theta' = (\lambda, \beta', \sigma^2) \). The BC likelihood function under normality assumption of the error terms is given by

\[
\log L(\theta) = \sum_{t} \left[ \log \phi\left(\frac{(z_t - x_t' \beta)}{\sigma}\right) - \log \sigma \right] + (\lambda - 1) \sum_{t} \log y_t, \sigma
\]

where \( \phi \) is the probability density function of the standard normal assumption and \( \sigma^2 \) is the variance of \( u_t \) under homoscedasticity.
• The BC MLE cannot be consistent generally even if the error terms are homoscedastic.

• Although Nawata (2013) proposed semiparametric estimators, these estimators are also not consistent under heteroscedasticity.
• Therefore, it is necessary for us to test these two assumptions in order to use the BC MLE.
• The test has two parts, reflecting the two necessary conditions.
• We first test the “small $\sigma$” assumption based on the methods considered by Nawata (2013a) and Nawata and Kawabuchi (2014).
Nawata [32] proposed a semiparametric estimator (hereafter, N-estimator), obtained by:

$$G(\theta) = -\frac{1}{\sigma^2} \sum_{i,j} \frac{(\lambda x_{ij}' \beta + 1)\log(\lambda x_{ij}' \beta + 1)}{\lambda} - \lambda x_{ij}' \beta (z_{ij} - x_{ij}' \beta) + \log(\lambda x_{ij}' \beta + 1)(z_{ij} - x_{ij}' \beta)^2 \quad (3).$$

$$+ \frac{\lambda (z_{ij} - x_{ij}' \beta)^3}{\lambda x_{ij}' \beta + 1} + \sum_{i,j} \frac{1}{\lambda} \log(\lambda x_{ij}' \beta + 1) + \frac{(z_{ij} - x_{ij}' \beta)}{\lambda x_{ij}' \beta + 1} = 0,$$

$$\sum_{i,j} x_{ij}(z_{ij} - x_{ij}' \beta) = 0, \quad \text{and} \quad \sigma^2 = \sum_{i,j} \frac{(z_{ij} - x_{ij}' \beta)^2}{n}.$$ 

These equations are available by the approximation of the $\frac{\partial \log L}{\partial \theta}$. Using the BC MLE and N-estimator, we can conduct the test for the “small $\sigma$” assumption (the null hypothesis is that the “small $\sigma$” assumption holds) by the Hausman test [33].
Appendix A: Approximation of $\frac{\partial \log L}{\partial \lambda}$

Here,

$$\frac{\partial \log L}{\partial \lambda} \bigg|_{\theta_0} = -\frac{1}{\sigma_0^2 \lambda_0} \sum_t \{y_t^\lambda_0 \log(y_t) - z_t^*\}u_t + \sum_t \log(y_t)$$  (14)

where $z_t^* = \{y_t^\lambda_0 - 1\}/\lambda_0$ if $\lambda_0 \neq 0$ and $z_t^* = \log(y_t)$ if $\lambda_0 = 0$. If $|\lambda_0 u_t/(\lambda_0 x_t' \beta_0 + 1)|$ is small and $\lambda_0 \neq 0$, we get

$$\log(y_t) = \frac{1}{\lambda_0} \log(\lambda_0 x_t' \beta_0 + 1 + \lambda_0 u_t) = \frac{1}{\lambda_0} \{\log(\lambda_0 x_t' \beta_0 + 1) + \log(1 + \frac{\lambda_0 u_t}{\lambda_0 x_t' \beta_0 + 1})\}$$

$$\approx \frac{1}{\lambda_0} \log(\lambda_0 x_t' \beta_0 + 1) + \frac{u_t}{\lambda_0 x_t' \beta_0 + 1}. \quad (15)$$

Therefore, if $\lambda_0 \sigma_0/(\lambda_0 x_t' \beta_0 + 1) \approx 0$ for all observations (following Bickel and Doksum (1981)), I call “small $\sigma$” cases, we get

$$\frac{\partial \log L}{\partial \lambda} \bigg|_{\theta_0} \approx -\frac{1}{\sigma_0^2 \lambda_0} \sum_t \{\frac{(\lambda_0 x_t' \beta_0 + 1)\log(\lambda_0 x_t' \beta_0 + 1)}{\lambda_0} - x_t' \beta_0\}u_t + \log(\lambda_0 x_t' \beta_0 + 1)u_t^2 + \frac{\lambda_0 u_t^3}{\lambda_0 x_t' \beta_0 + 1}$$

$$+ \sum_t \{\frac{1}{\lambda_0} \log(\lambda_0 x_t' \beta_0 + 1) + \frac{u_t}{\lambda_0 x_t' \beta_0 + 1}\} = G_T(\theta_0).$$
(Hereafter, we refer to this estimator as the N-estimator.) The asymptotic distribution of the N-estimator $\hat{\theta}_N' = (\hat{\lambda}_N, \beta_N', \sigma_N^2)$ is given by:

$$\sqrt{T}(\hat{\theta}_N - \theta_0) \to N[0, A^{-1}B(A')^{-1}], \quad \text{(5)}$$

where $A = -E[\frac{\partial \ell_t(\theta)}{\partial \theta'} | \theta_0]$, $\quad B = E[\ell_t(\theta_0)\ell_t(\theta_0)']$, $\quad \ell_t(\theta)' = [g_t(\theta), \xi_t(\theta)', \varsigma_t(\theta)]$, $\quad \xi_t(\theta) = \frac{1}{\sigma^2} x_t(z_t - x_t' \beta)$, and $\quad \varsigma_t(\theta) = \frac{(z_t - x_t' \beta) - \sigma^2}{2\sigma^2}$. \quad
\[ \frac{\lambda_0 \sigma_0}{(1 + \lambda_0 x_i' \beta_0)} \to 0, \] the BC MLE is not only a consistent

but also an efficient estimator, and the “small \( \sigma \) asymptotics”

of the BC MLE \( \hat{\theta}_{BC} = (\hat{\lambda}_{BC}, \hat{\beta}_{BC}, \hat{\sigma}^2_{BC}) \) are obtained by

\[ \sqrt{T}(\hat{\theta}_{BC} - \theta_0) \to N(0, C^{-1} BC^{-1}) \] \( (6) \)

where \( C = -E[\frac{\partial^2 \log L}{\partial \theta \partial \theta'} |_{\theta_0}] \).
Since \( G_T(\theta_0) = \left. \frac{\partial \log L}{\partial \lambda} \right|_{\theta_0} \) under the “small \( \sigma \)” assumption, we get:

\[
\sqrt{T}(\hat{\lambda}_N - \hat{\lambda}_{BC}) \to N(0, \delta),
\]  

(7)

where \( \delta = \) the first element of \( (A^{-1} - C^{-1})B(A^{-1} - C^{-1})' \). Hence we can perform a more precise test than one in which the asymptotic variance is calculated by the difference between two variances, such as the Hausman-type test (1978). Using \( t = \sqrt{T}(\hat{\lambda}_N - \hat{\lambda}_{BC})/\sqrt{\hat{\delta}} \) as the test statistic, where \( \hat{\delta} \) is the estimator of \( \delta \), we can test the “small \( \sigma \)” assumption; that is, we can test whether we can successfully use the BC MLE or not.
Since \( G_T(\theta_0) = \frac{\partial \log L}{\partial \lambda} \bigg|_{\theta_0} \) under the “small \( \sigma \)” assumption, we get

\[
\sqrt{T}(\hat{\lambda}_N - \hat{\lambda}_{BC}) \to N(0, \delta), \quad (7)
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When $\lambda_0 = 0$, we substitute $\lim_{\lambda_0 \to 0} A$, $\lim_{\lambda_0 \to 0} B$, and $\lim_{\lambda_0 \to 0} C$ for $A$, $B$, and $C$, and the test can be performed using the same formula.

Since the rank of the asymptotic variance-covariance matrix of $[\sqrt{T} (\hat{\lambda}_{BC} - \hat{\lambda}_N), \sqrt{T} (\hat{\beta}_{BC} - \hat{\beta}_N)']$ asymptotically becomes one, we cannot use any element of $\beta$ in the Hausman-type test (Nawata and McAleer, 2014).
The maximum number of parameters for the Hausman test when the estimators are from different sets of equations

Kazumitsu Nawata\textsuperscript{a,\,*}, Michael McAleer\textsuperscript{b,c,d,e}

\textsuperscript{a} Graduate School of Engineering, University of Tokyo, Japan
\textsuperscript{b} Department of Quantitative Finance, National Tsing Hua University, Taiwan
\textsuperscript{c} Econometric Institute, Erasmus School of Economics, Erasmus University Rotterdam, The Netherlands
\textsuperscript{d} Tinbergen Institute, The Netherlands
\textsuperscript{e} Department of Quantitative Economics, Complutense University of Madrid, Spain
• However, these estimators are inconsistent under heteroscedasticity.
Nawata (2015) considered the first- and third-moment restrictions and consider the roots of the equations.

\[ G_T(\theta) = \sum_t g_t(\theta) = 0, \quad g_t(\theta) \equiv g(\theta, x_t, y_t) = (z_t - x_t' \beta)^3 \quad \text{and} \quad \sum_t x_t (z_t - x_t' \beta) = 0, \quad (2) \]

where \( \theta = (\lambda, \beta) \). Although Nawata (2013) considered more complicated moment restrictions for \( G_T(\theta) \) obtained by the modification of the likelihood function of the BC model, a simple third-order moment restriction is used in this paper. Note that the first equation in (2) gives the least-squares estimator when the value of \( \lambda \) is given. Let \( \theta_0' = (\lambda_0, \beta_0) \) be the true parameter value of \( \theta \). Since \( E[G(\theta_0)] = 0 \), we obtain a consistent estimator.

But the results of Monte Carlo study show that the variance of the estimator is large.
Nawata and Kawabuchi (2016), we consider the roots of the equations,

\[ M_n(\theta) = \sum_{i,j} m_{ij}(\theta), \quad (3) \]

\[ m_{ij}(\theta) = -\frac{1}{\lambda \sigma^2} \left[ \frac{(\lambda x_{ij}' \beta + 1) \log(\lambda x_{ij}' \beta + 1)}{\lambda} - x_{ij}' \beta \right] (z_{ij} - x_{ij}' \beta) + \log(\lambda x_{ij}' \beta + 1) + \frac{\lambda (z_{ij} - x_{ij}' \beta)^3}{\lambda x_{ij}' \beta + 1} \]

\[ + \frac{z_{ij} - x_{ij}' \beta}{\lambda x_{ij}' \beta + 1} \quad \text{if} \quad \lambda \neq 0, \]

\[ m_{ij}(\theta) = \lim_{\lambda \to 0} m_{ij}(\theta) = -\frac{1}{\sigma^2} (z_{ij} - x_{ij}' \beta)^3 + (z_{ij} - x_{ij}' \beta) \quad \text{if} \quad \lambda = 0, \]

\[ \sum x_{ij}(z_{ij} - x_{ij}' \beta) = 0, \quad \text{and} \quad \sigma^2 = \sum_{i,j} \frac{(z_{ij} - x_{ij}' \beta)^2}{n}. \]
If \( E(u_{ij} | x_{ij}) = E(u_{ij}^3 | x_{ij}) = 0 \), there exists a consistent estimator of \( \lambda \) and \( \beta \) among the roots of Equation (4). Let \( \hat{\theta}_N = (\hat{\lambda}_N, \hat{\beta}_N, \hat{\sigma}^2_N) \) be the consistent root (hereafter, N-estimator), \((\lambda_0, \beta_0')\) be true parameter values, \( \bar{\sigma}^2 = \lim_{n \to \infty} \frac{1}{n} \sum_{i,j} \sigma^2_{ij} \) and \( \theta_0 = (\lambda_0, \beta_0, \bar{\sigma}^2) \). The asymptotic distribution of this estimator \( \hat{\theta}_N \) is given by:

\[
\sqrt{T} (\hat{\theta}_N - \theta_0^*) \rightarrow N[0, A^{-1}B(A')^{-1}],
\]

(10).

where \( A = -p \lim_{n \to \infty} \frac{1}{n} \frac{\partial \xi}{\partial \theta} \bigg|_{\theta_0} \), \( \xi(\theta)' = [M(\theta), \sum_{i,j} (z_{ij} - x_{ij}' \beta)x_{ij}', \sum_{i,j} (y_{ij} - x_{ij}' \beta)^2 - n\bar{\sigma}^2] \),

\( B = \lim_{n \to \infty} \frac{1}{n} \sum_{i,j} E \left[ \frac{\partial \xi_{ij}}{\partial \theta} \bigg|_{\theta_0} \frac{\partial \xi_{ij}}{\partial \theta'} \bigg|_{\theta_0} \right] \), and \( \xi_{ij}(\theta_0)' = [m_{ij}(\theta_0), x_{ij}'u_{ij}, u_{ij}^2 - \bar{\sigma}^2] \).
3. Evaluations of the LOS and DME

• 3.1 Data

• The data used in this study were collected by the Department of Health Care Economics at the Tokyo Medical and Dental University from over 100 hospitals; the sample period was from July 2008 to March 2012. The data included patients’ LOS, medical expenditures, age, gender, health-related conditions and medical treatments.

• The Institutional Review Boards of the University of Tokyo and Tokyo Medical and Dental University approved the use of this dataset.
• The original dataset included 27,861 patients, and 22,430 patients (80%) were classified under the DPC code 100070xxxxxx0x (type 2 diabetes patient without diabetic ketoacidosis and secondary diseases).

• The ALOS and average medical expenditure (AME) for these patients were 17.4 days and 461,431 yen, respectively.

• This means that 77% of medical expenditures for diabetes were for these patients.
• As in the previous study [24], we only used the data of patients: (i) who were treated in clinical departments that mainly treat diabetes; and (ii) whose principle disease was diabetes.

• Of the 21,603 patients who satisfied these criteria, 14,193 were regular patients. Diabetes can cause complications that require serious operations. It is natural that LOS would become longer and medical expenditures higher for these patients.
Therefore, we excluded 932 patients who had received operations (ALOS and AME for patients with operations were 28.5 days and 882,378 yen, respectively).

Finally, we used a data set of 12,666 patients in 60 hospitals (Hp1-60) with more than 60 regular patients to evaluate the effects of patients.
• For all 12,666 patients, ALOS was 18.1 days with a standard deviation (SD) of 12.7 days.
• The AME was 461,680 yen with a SD of 273,253 yen.
• In the case of educational hospitalization, the ALOS was 13.7 days with a SD of 6.7 days, and the AME was 370,336 yen with a SD of 152,895 yen for 6,178 patients. Therefore, the ALOS was 4.4 days longer and AME was 91,344 yen higher for regular patients than for those with an educational hospitalization [24].
• Moreover, the coefficients of variation (\(=\text{SD/average}\)) became 70% for LOS and 59% for medical expenditures. The coefficients of variation were 49% and 41% for the educational hospitalizations.

• This means that heterogeneity of regular patients was larger than that of educational hospitalization, as expected.
• The maximum ALOS by hospital was 37.6 days (hp50) and the minimum was 10.0 days (hp42). The maximum was thus 3.8 times larger than the minimum, with a difference of 27.6 days.

• The maximum SD by hospital was 28.4 days (hp21), and the minimum was 4.7 days (hp52). This maximum was six times larger than the minimum and the variances were quite different among hospitals.

• This implies the importance of the proposed model, which takes into account the heteroscedasticity of the variances.
Figure 1 shows the relationship between the ALOS and AME by hospital.
The correlation coefficient was 0.984, and there was an almost linear relation between these two variables.
This implies that despite large heterogeneity among patients, ALOS was the largest determinant of AME.
3.2 Evaluation of LOS

![Graph showing the distribution of LOS of regular patients.](image)

Figure 2. Distribution of LOS of regular patients
Table 3. Distribution of LOS
Equation (1) becomes:

\[ x_{ij}' \beta = \beta_1 \text{Female} + \beta_2 \text{Age} + \beta_3 \text{Age 70} + \beta_6 \text{Comorbidities} + \beta_5 \text{Complications} \]

\[ + \beta_6 \text{Acute Hospitalization} + \beta_7 \text{Outpatient} + \beta_8 \text{Introduction} + \beta_9 \text{Home} \]

\[ + \beta_{10} \text{One Week} + \beta_{13} \text{Over SHP} + \sum_{\ell} \beta_{\ell} \text{ICD-10 dummy} + \sum_{i} \beta_i \text{-th Hospital Dummy} \]
We first tested the “small $\sigma$” assumption. The estimates of $\lambda$ were 0.3537 for the BC MLE and 0.3785 for the N-estimator. The value of the test statistic was $t = (0.3537 - 0.3785)/0.0338 = 1.775$ and the null hypothesis was accepted at the 5% level. Therefore, we used the residuals of the BC MLE in the test for heteroscedasticity. We got $\sqrt{n} \sum_{i,j} (f_{1ij} - f_{2ij})e_{ij}^2 = 0.0398$ and $\sqrt{V_1} \leq \sqrt{V_2} + \sqrt{V_3} = 0.0121$, and the value of the test statistic was $t \geq 3.281$. The null hypothesis was rejected at the 1% level; thus, we could not use the BC MLE and had to use the newly proposed estimator.
• The estimation results are presented in Table 2. The estimate of $\lambda$ was 0.4824, which was sufficiently larger than that of the BC MLE. This coincides with the results of the Monte Carlo study [34], where the BC MLE underestimated $\lambda$ under heteroscedasticity. *The results of other variables were similar to those for educational hospitalization.*
The estimate of Age, Comorbidities, Complications and Introduction dummy were positive and significant at the 1% level. This means that LOS was prolonged by age and complications. The LOS also became longer if patients came from another hospital. The estimate of After 2010 dummy was negative and significant at the 5% level, and it was admitted that the 2010 revision reduced LOS. The estimates of the Female, Age 70, Acute Hospitalization, Outpatient, Home, Winter and Summer dummies were not significant at the 5% level, and we could not find evidence that the LOS depended on these variables.
• The estimates of **One Week and Over SHP dummies** were positive and significant at the 1% level, showing that one-week hospitalization and exceeding the SHP affected LOS.

• With respect to the ICD-10 dummies, the estimates of **E11.5** and **E11.7** were positive and significant at the 1%, as was E11.6 at the 5% level; none of the other estimates was significant at the 5% level.
• For the hospital dummies, the maximum estimate was 6.111 (HP50), the minimum was 3.238 (HP52), and the difference was 2.873.
<table>
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<th>Variable</th>
<th>Estimated</th>
<th>SE*</th>
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SE: Standard Error, *Significant at the 5% level, **Significant at the 1% level
3.2 Evaluation of DME

Next, we evaluated daily medical expenditures ($DME_{ij}$) per patient. Since the distribution was not skewed, we used the OLS for the analysis of DME. Since heteroscedasticity of error terms might exist, the standard errors were obtained by the robust variance calculation method [35]. We considered the model given by:

$$DME_{ij} = \beta_1 \text{Female} + \beta_2 \text{Age} + \beta_3 \text{Age 70} + \beta_6 \text{Comorbidities} + \beta_5 \text{Complications} \quad (12)$$

$$+ \beta_6 \text{Acute Hospitalization} + \beta_7 \text{Outpatient} + \beta_8 \text{Introduction} + \beta_9 \text{Home} + \beta_{10} \text{LOS}$$

$$+ \beta_{11} \text{Over SHP} + \beta_{12} \text{Over SHP *(LOS - SHP)} + \sum \beta_i \text{ICD-10 dummy}$$

$$+ \sum \beta_i \text{ i-th Hospital dummy}$$
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SE: Standard Error, *Significant at the 5% level, **Significant at the 1% level
• The medical expenditures of 129 patients were not available, and the DME of 42 were too low (below 10,000 yen). Excluding these patients, we used the dataset of 12,495 patients. The results of the estimation are presented in Table 3. The average daily medical expenditure (ADME) for regular patients was 27,375 yen, a little bit smaller than the ADME for educational hospitalization (27,983 yen) [24].
• The estimates of Comorbidities and Complication were positive and significant at the 1% level. Thus, we found that comorbidities and complications not only made LOS longer but also DME higher.

• The estimates of Acute Hospitalization and Outpatients were significant at the 1% level but the signs were opposite. Acute hospitalization made DME higher but it were smaller if a patient was a hospital’s own outpatient.
• The estimates of Winter and Summer were positive and significant at the 1% and 5% levels, respectively. In this case, we observed a seasonal effect.

• The estimate of After 2010 was positive and significant at the 1% level.
The estimate of LOS was negative and significant at the 1% level. Since daily payments to hospitals decrease as LOS becomes longer under the DPC/PDPS, this result is quite reasonable. On the other hand, estimates of Over SHP and Over SHP *(LOS - SHP) were positive and significant at the 1% level. After the SHP, payment is based on a conventional fee-for-service system, and we got the same result as for the educational hospitalization cases.
• The coefficient time was negative and significant at the 1% level, and there was a time trend that reduced DME. Among the ICD-10 dummies, E11.2, E11.4 and E11.7 were positive at the 1% or 5% levels, and the DME increased for these diseases.

• Among estimates of hospital dummies, the largest was 36,920 yen (HP28) and the smallest was 33,553 yen (HP49). The difference was 3,368 yen or 12.3% of the ADME of all patients.
4. Discussion

• OECD states that “With health budgets already under great pressure and national budgets severely strained, ... we must find ways to prevent and manage diabetes in a cost-effective manner.”

• In keeping with this statement, we believe that the efficiency of medical treatments must be considered as a possible means of controlling medical expenditures in future Japanese medical policies.
• We found surprisingly large differences among hospitals for ALOS.

• This indicates that even after eliminating the influences of the patient characteristics and principle diseases, there were surprisingly large differences among hospitals.
The large differences of ALOS are accepted only if a long LOS will sufficiently improve the conditions of patients. Treatments of type 2 diabetes are:

- lifestyle improvements
- Oral pills
- insulin injections
• Here, we consider lifestyle improvement guidances, such as improved diet and exercises, rather than medical treatment.
• It is considered that educational hospitalization can be easier to standardize LOS.
• Nagashima et al. (2005) reported that there were no differences in the effects of educational hospitalization between four-day (three-night) and two-week stays.

• Yamamoto, Takeuchi and Ichikawa (2000) reported that i) the ALOS was shortened from 25.2 days to 14.6 days, ii) cooperation among medical staff became easier, and iii) the scores of comprehensive tests were improved by the introduction of a critical path and standardization of educational programs.
• Kobori et al. (2006) reported that ALOS was shortened from 14 days to 10 days by changing from a paper-based to a computerized critical path with similar outcomes.
• Tsurumi (2002) reported that introduction of a critical path and standardization of treatments made cooperation among medical staff easier and improved understanding of diabetes and fasting therapy blood sugar tests.

• No studies showed benefits of long (such as two weeks or more) LOS in educational hospitalization.
• As mentioned earlier, the major goal of this study was to evaluate whether we can possibly control medical expenditures without degrading the quality of medical treatments.

• In the case of this disease, the answer seems to be yes: medical expenditures could be reduced significantly by reducing LOS without degrading the effects of hospitalization.
• This means that hospitalization costs could be saved by reducing the LOS.

• For that purpose, i) introduction of clinical path, and ii) improvement and standardization of educational programs are important, especially for hospitals with a long ALOS.
• Reducing ALOS can also benefit patients.

• It is difficult for the working generation to stay in a hospital for a long period of time (two weeks or more). Therefore, long LOS might prevent working-age patients in the early stages of diabetes from getting proper treatment. The Japanese standard retirement age is 65, and the average age of patients was 64, with more than half of patients aged 65 or younger.
• A shorter ALOS reduces costs of hospitalization (including opportunity costs) for patients, and more (potential) patients can treat diabetes at early stages if costs are reduced.

• As pointed out earlier, the risk of type 2 diabetes can be controlled through lifestyle improvements.
• In our dataset, only 131 regular patients out of 14,193 were reported as complete recoveries; that is, at least 99% of patients required medical care after leaving the hospital.

• Moreover, a large number of patients do not follow prescribed therapies. Dilla et al. [39] reported that it was possible to control medical expenses by reducing body mass index (BMI).
• Although compared to non-diagnosed individuals at risk for high blood sugar, diagnosed diabetics are more likely to improve their lifestyle, the effect diminishes and some behavioral responses to diabetes may be short-lived.

• Therefore, systems that take proper care of patients for long periods of time after hospitalization are absolutely necessary for diabetes.
• However, such systems are not yet sufficiently established [22], and we need to institute them as soon as possible.

• For the development of new systems, adoption of health-information technologies and proper budget allocation are considered critically important.

• The differences of social and cultural factors should also be considered.
• Incentives to improve the efficiency of hospitals must be considered in the future revision of the medical payment system.
Japan 2035

Leading the World through Health
The advisory committee of the Ministry of Health, Labour and Welfare [3] released a very important report called “Japan vision: Healthcare 2035.” Financial Sustainability is one of the most important issues in this report. It emphasizes that “Transfer authority to prefectures” by 2035 and proposes a rather radical policy; that is, standard growth rates of medical payments shall be assigned to prefectures.
• If a payment of a prefecture exceeds a predetermined growth rate, the prefecture will be able to cut payments to hospitals and clinics in that prefecture to by changing conditions for payments. (In Japan, basic payments are determined by the government and if a hospital satisfies certain conditions, it can receive additional payments.)
• However, implementation of this rather radical policy seems to be not easy. The better strategy is improving efficiencies of hospitals and medical treatments to control expenditures without degrading treatment outcomes for financial stability.

• They should be done before introduction of the policy proposed by “Japan vision: Healthcare 2035.”