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Exploring the causal relationship between length of stay in hospitals and treatment outcome: Evidence from Japanese AMI patients*

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【Abstract】In this study, we explore the causal relationship between length of stay (LOS) in hospitals and the treatment outcome for Acute Myocardial Infarction (AMI) patients in Japan, where the average LOS (ALOS) is the longest among OECD countries. Using chart-based data, we address the endogeneity between LOS and treatment outcome by using an exogenous variation based on Rokuyo (the six basic labels allocated to each weekday), which is found to be irrelevant to admission day but relevant to discharge day. While we do find a significant association between LOS and rehospitalization probability in the ordinary least squares (OLS) estimation, we do not find a significant relationship once LOS is instrumented by the six basic labels in various instrumental variable estimations. This implies that additional stay that was induced owing to patient's choice of preferred Rokuyo at discharge has no effect on rehospitalization probability.

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1. Introduction

In this study, we carefully explore the causal relationship between length of stay (LOS) in hospitals and treatment outcome for acute myocardial infarction (AMI) patients in Japan. This is a controversial topic stemming from a serious concern regarding the rapidly expanding medical care expenditure in Japan. We focus on a unique Japanese feature to provide new quantitative evidence on the causal effect of LOS on treatment outcome, which is relevant to health economists and policymakers within and outside Japan.

Internationally, the health/medical aspects in Japan are considered to have efficient features. First, the general health status of the Japanese is well shaped, which is evident from the high life expectancy and the very low infant mortality (WHO, 2013).[1] Second, health expenditure is relatively low in Japan. Both the relative proportion of total health expenditure to GDP and per capita expenditure in Japan are close to the average of OECD countries. Third, Japan established a mandatory health care system in 1961, providing universal medical coverage linked to jobs or regions of residency through employers or municipalities, where the government determines the national fee schedule (including drug fees) that is applicable to all providers. These characteristics illustrate that the Japanese population enjoys better health and longer life expectancy at a relatively lower cost of access to medical care for those who are insured.

In contrast to these aspects, the average length of stay in hospitals (ALOS)—which is often used as an indicator of health efficiency—is much longer in Japan as compared to other OECD countries (OECD, 2011). Figure 1 illustrates the cross-country comparison among OECD countries in terms of ALOS and curative (acute) care beds per 1,000 people (OECD, 2013). The ALOS, for all causes, is 18.2 days in Japan, which is substantially higher than that in

[1] By causes of mortality, the number of deaths per 100,000 people owing to AMI, cancer, or diabetes mellitus is much lower in Japan than the OECD average (OECD, 2013). In addition, risk factors related to daily smoking, overweight or obese population, and adult alcohol consumption is lower in the total Japanese population.

OECD countries (7.5 days) and close to four times that in the US (4.8 days).[2] On the other hand, the number of curative care beds per 1,000 people is 8.0 in Japan, which is much higher than the OECD average of 3.4; moreover, the ratio of practicing physicians per 1,000 people is 2.2, which is lower than the OECD average of 3.2.[3]

Owing to rapid aging in Japanese society, health expenditure has also been steadily increasing both in terms of the absolute and relative amounts to GDP; this is expected to expand further in the future with a larger proportion of the elderly having higher per capita expenditures (National Council on Social Security, 2006). The Japanese government considers the longer ALOS compared with other developed countries as one of the causes of the increasing medical expenditure in Japan, based on the observed positive correlation between per capita inpatient medical expenditure for the elderly and the ALOS among prefectures. Under the uniform fee-for-service system prevalent in hospitals, a longer hospitalization term appears justified since the "price" for hospitalization does not change. Indeed, according to OECD (2011), "[t]he abundant supply of beds and the structure of hospital payments in Japan provide hospitals with incentives to keep patients longer. Financial incentives inherent in hospital payment methods can also influence length of stay in other countries."

The Japanese government has revised the fee-for-service schedule for either acute or chronic hospitals in order to encourage hospitals to discharge patients earlier. In 1991–92, the government increased a patient's out-of-pocket hospitalization fee[4], established a reward fee for shorter hospitalization, and introduced convalescent wards in a general hospital for long-term hospitalized patients. Moreover, in 1998, the government began to lower the hospitalization fee of general hospitals offering acute medical care if a patient aged 75 or over is hospitalized for over 90 days (Izumida, 2004; Yamamoto, 2004) and introduced the public long-term care insurance program in 2000. During this period, the ALOS—excluding that in chronic

[2] For Japan, the ALOS data refers to ALOS for acute care, excluding long-term care beds in hospitals (OECD, 2013).
[3] In contrast, the density of nurses is higher in Japan than the OECD average.
[4] The reform is legislated by the Revision of Law of Health and Medical Services for the Elderly (Rojin Hoken Hou).

hospitals—substantially declined from 34.4 days in 1994 to 17.9 days in 2012, although it is still the longest in Japan among OECD countries.[5]

Further, the government and each prefecture was required to establish a "Plan for Effective Medical Expenditure" (Iryohi Tekiseika Keikaku) for the 2008–2013 period; the main objective of this plan is to reduce the ALOS so that the gap between the ALOS among prefectures and the shortest LOS among prefectures (Nagano Prefecture) is halved by 2015.[6] In parallel with the change in incentives for hospitals, in 2003, the Diagnostic Procedure Combination (DPC)—an inpatient prospective payment system—was introduced for "special function hospitals"; this was considered the Japanese counterpart of the Medicare Prospective Payment System (PPS) in the US (Anderson and Ikegami, 2011), which aimed to reduce the variation in health expenditure and LOS across hospitals.[7]

While a reduction in the LOS in hospitals has been a focal point in medical reform in Japan, it is important to consider the effect of shorter LOS on treatment outcome, but not merely by relying on a simple "the shorter, the better" discussion that assumes that all other things are equal. A shorter LOS may reduce the cost per discharge and shift care from inpatient to less expensive post-acute settings (OECD, 2011). On the other hand, if a longer LOS contributes to a better treatment outcome, a shorter LOS may have an adverse effect on treatment outcome. Moreover, shorter LOS may need more intensive and costly services per day and could lower the comfort and recovery of the patient and increase the readmission rate, thereby resulting in a higher cost per episode of illness.[8]

Thus, when exploring the causal effect of LOS on treatment outcome, we need to consider

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[5] Izumida (2004) examined the effect of change in fee for hospital services on LOS in 1997, 1998, and 2000, and found that the 1997 and 1998 reforms affected the LOS in hospitals.

[6] The plan has a legal basis in the Act on Assurance of Medical Care for Elderly People (Koreisha no Iryo no Kakuho ni kansuru Horitsu), which has been effective from April 2008.

[7] Anderson and Ikegami (2011) summarized the following concerns on Japan's DPC acute hospital payment system: (1) a hospital-specific conversion factor that adjusts payments made by the DPC system, (2) a significant proportion of payments that are made outside the DPC system, (3) the number of cases for which payment is made outside the DPC system, (4) the per day payment system, (5) specific adjustments based on hospital behavior, and (6) the auditing mechanisms.

[8] Tokunaga and Imanaka (2002) argue that aspects that determine patient satisfaction depend on the LOS in Japanese hospitals.

the endogenous relationship. One direction for addressing this endogeneity is to focus on a "natural experiment," which is represented by any policy or institutional changes. Evans et al. (2008) carefully examined the impact of state and federal laws designed to increase the length of postpartum hospital stay that substantially reduced the proportion of newborns discharged early. A simple OLS estimation revealed that a shorter postpartum hospital stay is correlated with better health since healthier babies are discharged sooner. In contrast, a 2SLS estimation using a series of laws changed in the late 1990s as instrumental variables revealed that an increase in the length of postpartum hospital stay is unrelated to the baby's health. They concluded that the average effect of longer postpartum LOS on the probability of readmission is small, but it can be highly cost effective for high-risk babies.

To the best of our knowledge, no existing research in Japan explores the causal effect of LOS on treatment outcome. Extending the scope to recent studies outside Japan, Kociol et al. (2012) examined data on AMI patients from 17 countries and found a substantial variation in the 30-day readmission rate and LOS across the countries (not including data from Japan); the 30-day readmission rates were higher for the US than other countries, while the median LOS was shortest for US patients (3 days) and longest for Germany (8 days). Then, they found that the difference in the 30-day post-discharge readmission rate after ST-segment elevation myocardial infarction (STEMI) treatment across countries is greatly attenuated after adjustment for LOS. On the other hand, Saczynski et al. (2010) observed that LOS after AMI treatment significantly declined from 7.2 days to 5.0 days between 1995 and 2005 in the US; however, they found that a declining LOS is not associated with an increased risk for early readmission or all-cause mortality.[9]

In this study, we adopt an alternative approach to address the endogeneity issue to provide new persuasive evidence. *Rokuyo* is a label on Japanese calendars and pocket diaries that indicates one's good or bad luck, direction, or fortune for each day. *Rokuyo* comprises six basic

[9] The sample was 4,184 patients hospitalized with AMI in a central New England metropolitan area during 6 annual periods (1995, 1997, 1999, 2001, 2003, 2005). The findings are not changed across year under study.

labels that include *Sensho*, *Tomobiki*, *Senbu*, *Butsumetsu*, *Taian*, and *Shakkou* to indicate how auspicious a given day is.[10] *Rokuyo* is a rather popular and prevalent superstition in Japan where most people know the statements on formal (ceremonial) occasions such as "a marriage party should not made on a *Butsumetsu* day" and "a funeral day should not take place on a *Tomobiki* day," regardless of whether they believe this. Since AMI is an acute disease, a patient usually cannot choose a *Rokuyo* day on admission, but can do so for discharge. In other words, a patient who is going to be discharged can avoid a *Butsumetsu* (unlucky) day and even wait for the next *Taian* (lucky) day.

Indeed, subsequent sections show that the days of admission for AMI patients are random across *Rokuyo*, but those of discharge are clearly more concentrated on a *Taian* day and less on a *Butsumetsu* day. Thus, the *Rokuyo* day at the time of discharge is a valid instrument since it is related to LOS, but not related to treatment outcome. One might argue that a patient who suffered a serious heart attack is more likely to choose a good day for discharge, and thus, the *Rokuyo* day is not purely unrelated to treatment outcome. However, our data—which corresponds to the Cooperative Cardiovascular Project (CCP) in the US—provides a variety of indicators of the severity levels of AMI, which enable us to control for the seriousness of the AMI that a patient has undergone. Moreover, as we discuss below, the correlation coefficients between the discharge *Rokuyo* and explanatory variables are low—less than 0.1.

The remainder of this manuscript is organized in the following manner. In Section 2, we describe the data used in the estimation and provide evidence of the *Rokuyo* day on

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[10] The Japanese "roku" means "six". The origin of *Rokuyo* is unclear but was imported from China to Japan in the 14th century. Interestingly, *Rokuyo* gained the popularity after the World War Second. The definition for each label is as follows (Takano et al. (2011) except *Shakko*).
Butsumetsu: (the) Buddha's death; a very unlucky day according to traditional almanacs.
Taian: a lucky [an auspicious] day (on the Japanese calendar).
Senshou: a day on which bold actions are supposed to turn out well; a day supposed to be lucky in the morning and unlucky in the afternoon.
Senbu: a day on which it is supposed to be better to avoid disputes and hurried actions; a day supposed to be unlucky in the morning and lucky in the afternoon.
Tomobiki: a day on which one's bad luck is thought to affect one's friends, and which is therefore avoided when scheduling funerals
Shakko: a day which is lucky during the hour of the horse (11 am–1 pm) but the luck is bad for the rest.

admission/discharge. In Section 3, we conduct a regression analysis to explore the relationship between LOS and treatment outcome with alternative specifications. In Section 4, we provide various robustness checks on our main results. In Section 5, we present the conclusion.

2. Data description and *Rokuyo* at admission and discharge

In Japan, it is fair to say that large-scale patient-level data that is internationally comparable is scarce. An exception is the Tokai Acute Myocardial Infarction Study (TAMIS), whose objective is to create a database comparable to the Cooperative Cardiovascular Project (CCP). The CCP is designed to improve the quality of care for Medicare beneficiaries with AMI. TAMIS aims to investigate the variation in the quality of healthcare with respect to treatments and outcomes between the US and Japan, controlling for chart-based detailed clinical information on AMI patients.[11] In addition to rich information on individual characteristics, comorbidity and severity at admission, TAMIS provides data that is essential to this analysis—the dates of admission to and discharge from a hospital for each episode of illness, which enables us to identify on which *Rokuyo* day a patient was admitted and discharged.

The data collection enabled us to obtain abstracted charts pertaining to 3,274 heart attack patients who were newly hospitalized in 15 municipal or non-profit high-tech and high-volume general hospitals located in the Tokai area of Japan that provide coronary angiography (CAG) and percutaneous coronary intervention (PCI) between January 2001 and December 2003, the period when stent technology prevailed (called TAMIS-II Data)[12]. In the process of data collection, charts were carefully reviewed by research nurses and physicians in the standardized

[11] The CCP is undertaken by the Health Care Financing Administration (HCFA, currently called Center for Medicare and Medicaid Services: CMS). See the detailed description of the TAMIS project in Noguchi et al. (2008).

[12] See Hirakawa et al. (2005), Hirakawa et al. (2006), and Kimata et al. (2008). The TAMIS project also collected data on AMI patients during the period 1995–1997 in the same manner. Noguchi et al. (2008) used data for the period 1995–1997 to explore factors for the extraordinarily frequent use of percutaneous transluminal coronary angioplasty (PTCA) for the treatment of AMI and found that the probability of receiving PTCA is affected by the density of medical resources in a region; moreover, they found that medical expenditure was higher for treated patients but that there are no significant differences in hospitalization days between those who were treated and those who were not, thereby implying that the frequent use of PTCA is economically motivated.

manner of abstraction of medical records as done by the HCFA/CMS for the CCP. The record abstracts contain over 100 comorbid diseases and severity measures that collectively summarize all the major associated diseases and functional status impairments. Moreover, the abstracts include AMI severity measures following the CCP's expert advisory panel, which influence the appropriateness of major AMI treatment decisions and health outcomes (Noguchi et al., 2008).

Table 1 presents the frequency of *Rokuyo* days at admission and discharge as well as ALOS. The data demonstrates that *Rokuyo* days are random at admission (Column 1) and the ALOS is comparable regardless on which *Rokuyo* day a patient was admitted (Column 2). Table 2 presents the test statistics from the Kolmogorov–Smirnov test for equality of distribution of LOS by *Rokuyo* on admission and discharge days. As the table clearly shows, there is no significant difference in the distribution of LOS across *Rokuyo* on admission. On the contrary, the *Rokuyo* day of discharge is concentrated more on *Taian*, (21.9 percent) and less on *Butsumetsu* (13.2 percent) (Column (3) in Table 1). The pattern follows the ALOS by *Rokuyo* on discharge days (Column 4). The gap in the ALOS between *Taian* and *Butsumetsu* is 2.3 days. Further, Table 2 reveals that the distribution of LOS differs among some *Rokuyo*. In particular, the distribution of LOS on *Taian* is statistically different from that on *Butsumetsu*, *Sensho*, and *Senpu*. Further, that of *Senpu* is statistically different from *Tomobiki* in addition to *Taian*.

These observations demonstrate that the *Rokuyo* day of admission and the subsequent LOS are random. This is natural because a patient who has a heart attack needs to be hospitalized immediately and cannot wait to choose a suitable *Rokuyo* day for admission.[13] In contrast, it is evident that discharge is more frequent on *Taian* and less so on *Butsumetsu*. The non-random variation stems from the fact that a patient can choose (or wait for) a good *Rokuyo* day for discharge even if he/she no longer requires hospitalization. According to modern science, *Rokuyo* is a superstition and the choice of *Rokuyo* does not affect the treatment outcome for

[13] According to the guideline for AMI treatments, a doctor must make a diagnosis within 10 minutes after a patient arrives at the hospital, describe the treatment with the risks and benefits to the patient and family members, and begin treatment within 30 minutes (Uematsuse, 2002).

AMI patients.

Table 3 reports the descriptive statistics of individual demographics. We excluded the observations with missing variables among the listed ones. Further, we also excluded the observations of those patients who passed away during hospitalization. The probability of rehospitalization within one year, which is the treatment outcome variable in this study, is 39.3 percent. In this study, the definition of "rehospitalization" is the case in which a patient who received AMI treatment is readmitted within one year after discharge in the same hospital where the patient received the initial AMI treatment. If a patient passed away within one year after discharge, we considered this rehospitalization. It must be noted that we faced several issues related to the definition of rehospitalization. First, a patient may be re-hospitalized in a different hospital than the hospital where he/she received the initial treatment. In this case, we cannot trace the patient's rehospitalization. However, as discussed subsequently, the average age of the patients in the data is 65. Hence, it is not very realistic to imagine that elderly patients who have undergone an episode of AMI frequently move away from the place where they used to stay. Therefore, the bias arising from this concern could be minimal, if any. Second, the data was collected at 15 high-tech and high-volume medical facilities located in the Tokai area of Japan. Thus, we do not have information on potential patients admitted to more small-scale facilities that may be characterized as low-tech and/or low-volume; this may create a sample selection bias. However, generally speaking, an AMI patient is admitted to a health facility that is equipped with a certain high level of technology. Hence, the issue of sample selection caused by this problem may not be very serious. Third, the one-year time window of rehospitalization is arbitrarily determined by the authors, although this time-window appears to be a standard length for research purposes. In robustness checks, we change the time-window of rehospitalization to six months, nine months, and two years to ascertain whether our main results are affected. Fourth, while we can trace the death of patients after discharge if that happens, information on the cause of the death was not collected.

The average age of patients is 65 years and males account for over three-fourths of the sample. By type of medical insurance, over 60 percent of the patients in the sample are beneficiaries of National Health Insurance (NHI), followed by Employee Health Insurance and Mutual Assistance Insurance. The number of family members living with a patient is more than two and more than three-fourths of the sample has a spouse. The ALOS is 19.63 days. As mentioned in the previous section, the *Rokuyo* day at discharge is concentrated on *Taian* (22.1 percent), while that at admission is comparable across *Rokuyo*.

Table 4 reports the descriptive statistics of variables representing comorbidity and severity at admission. We converted all the information on comorbidity and severity at admission into dummy variables. The main reason for this is that in emergency cases such as AMI, it is difficult to collect all the detailed information on the patient, which may create many missing variables in the dataset. This would have forced us to exclude the observations on all such patients owing to missing data. To avoid this problem, we included "missing" as one category of dummy variables. Taking height as an example, approximately 20 percent (variable name: hei_y) of the patients' height is "unknown," which also makes it impossible to compute their Body Mass Index (BMI). Here, we use the word "unknown" and "missing" as synonyms. We face the choice of either excluding these observations or using a dummy variable for the missing variable, and adopt the latter method. As discussed earlier, one justification of using this method is rooted in practical reasoning. In emergency cases, collecting detailed information on patients is very difficult or occasionally even impossible. Thus, we interpreted the dummy variable representing missing data as information indicating the severity of a patient's condition. We use these created dummies in the econometric analyses presented in the next section (McClellan and Noguchi, 1997).

Examining comorbidity variables at admission, most patients in the sample are totally continent (98.3 percent) and are able to walk independently (96.7 percent). By incidence of type of disease, the most prevalent is current cigarette smoker (over 50 percent), followed by

hypertension (43.2 percent), and diabetes (any type, 27.8 percent). Moreover, 12.6 percent of the patients in the sample had CAG history and the proportion of PTCA history or CABG history was smaller. With regard to severity variables at admission, there is a non-negligible amount of missing data in temperature, mean arterial pressure (MAP), height, BMI, Albumin, EKG trace: transmural (new qwave), etc., thereby justifying using our dummy variable approach. Needless to say, myocardial infarction (MI) (excluding old MI) was detected by using EKG trace for 90 percent of the patients; 17.4 percent of the patients had transmural q wave, while 22 percent of them had congestive heart failure. The proportion of patients whose highest creatinine level is 25 or more was very small and the blood urea nitrogen level was normal for approximately 70 percent of the patients (variable name: bunsun1).

3. Estimation and results

In this section, we conduct a regression analysis to link LOS with treatment outcome. The specification is described in the following manner:

$$y_i = \alpha_0 + \sum_k \alpha_{1k} x_i + \sum_l \alpha_{2l} z_i + \varepsilon_i \ , \qquad (1)$$

where y_i is the dependent variable and refers to the dummy variable that takes the value of one if a patient is re-hospitalized within one year after discharge, and zero otherwise. The explanatory variables can be divided into two categories: x_i refers to the variables that indicate individual characteristics and health facility dummies (the variables shown in Table 3) and z_i refers to comorbidity and severity variables on admission. The last term, ε_i, is an error term.

Table 5 presents the estimation results based on a linear probability model using the OLS method.[14] The model includes fixed effects at the health facility level and the standard errors are also clustered at the health facility level. Column (1) reports the coefficients on x_i s,

[14] The results reported in the section are not altered if we employ a probit estimation.

excluding z_i s from the explanatory variables. The coefficient on LOS is positive and significant, thereby indicating that the longer a patient is hospitalized, the higher the probability of rehospitalization. Column (2) shows the estimated coefficients on both x_i s and z_i s, including comorbidity and severity variables at admission in the explanatory variables. Again, the coefficient on LOS is positive and significant, thereby implying that the longer a patient is hospitalized, the higher the probability of rehospitalization is. No individual characteristics are significant once comorbidity and severity variables at admission are included. Some comorbidity variables at admission such as hypertension, angina, family medical history of ischemic heart disease, renal failure, and CABG history are found to be positively statistically significant, thereby implying that these comorbidities have a positive correlation with the probability of rehospitalization. Similarly, some severity variables at admission such as high MAP, low weight, high level of white blood cells, and congestive heart failure are positive and statistically significant, thereby implying that these comorbidities have a positive correlation with the probability of rehospitalization.

In sum, the OLS estimation shows a positive and significant relationship between LOS and rehospitalization probability. However, we cannot interpret these findings as the causal association between LOS and rehospitalization. The positive association may simply show that a patient with a higher rehospitalization probability is more likely to be discharged later[15]. Another case is that there might be an unobservable factor that affects both LOS and probability of rehospitalization simultaneously (i.e., omitted variable bias), while it appears that there is almost no possibility of bias caused by measurement error because the variable we are concerned about for this bias is LOS, which is accurately measured in the data. In any case, we have to address this reverse causality or a possible bias caused by unobservable factors in capturing the causal effect of LOS on treatment outcome.

Thus, we conduct the estimation using instrumental variables in order to address the

[15] See Evans et al. (2008) for a similar positive relationship in the case of postpartum hospital days and health status of newborn babies.

endogeneity issue between LOS and the readmission probability. The instrumental variables are *Rokuyo* days at admission and discharge, which was reviewed in Section 2. Conceptually, the discharge *Rokuyo* is a valid instrument that is related with LOS but not related with treatment outcome. Moreover, the correlation coefficients between the discharge *Rokuyo* (IV) and explanatory variables are low—less than 0.1 in absolute value (results are omitted to save space but available upon request). We include *Rokuyo* day at admission as an instrumental variable too because the discharge day is partially affected by the day of admission, and the *Rokuyo* day at admission might affect the choice if discharge day given the order of the *Rokuyo* days.[16]

We implement two-stage least squares (2SLS), two-step generalized method of moments (GMM), and limited information maximum likelihood (LIML) estimations. Before we discuss the results, it is important to note the following aspects. First, as our OLS results show, omitting comorbidity and severity variables at admission from the specification of the outcome equation may cause a severe omitted variable bias. Thus, we applied the three aforementioned estimation methods to the specifications that include these variables. Second, because we cluster the observations at health facility level, the number of clusters is much smaller than the sum of the number of exogenous regressors and that of excluded instruments. In such a circumstance, the covariance matrix of orthogonality conditions is not full rank and GMM and overidentification tests are infeasible since the weighting matrix cannot be calculated. To solve this problem, a sufficient number of exogenous regressors is "partialled out" from all the other variables in the estimation for the weighting matrix to have full rank. Further, according to the Frisch–Waugh–Lovell (FWL) theorem (Frisch and Waugh, 1933; Lovell, 1963), in the two-step GMM estimation, the coefficients for the remaining regressors are the same as those that would be obtained if the variables were not partialled out when the coefficients of the partialled variables are not calculated. As a result of this procedure, in the results of the GMM estimation, we report

[16] The order of the *Rokuyo* days is fixed in the following manner: *Sensho*, *Tomobiki*, *Senbu*, *Butsumetsu*, *Taian*, and *Shakko*. However, the first day of January and July is set to be *Sensho*, that of February and August is *Tomobiki*, that of March and September is *Senbu*, that of April and August is *Butsumetsu*, that of May and November is *Taian*, and that of June and December is *Shakko* (all months are included in the old (lunar) calendar). In other words, the *Rokuyo* day begins in each lunar month with the first day in the same order.

only the coefficients of LOS—age, gender, number of family members living with a patient, and presence of spouse. This does not compromise the value of our approach because what we are interested in is the coefficient of LOS. Third, because there are numerous comorbidity and severity variables at admission, we do not report the coefficients of these variables. Although health facility dummies are included in the specification, they are omitted from the table.[17]

Table 6 reports the estimation results of the 2SLS, two-step GMM, and LIML as well as the result of the first stage of 2SLS. The dependent variable in the first stage is LOS, which is an endogenous variable in the second stage. The dummy for rehospitalization within one year is the dependent variable in the second stage. The result of the first stage of specification (1) indicates that the coefficient of *Taian* at discharge is positive and significant (base case is *Butsumetsu*). This implies that LOS on *Taian* discharge is longer than that on *Butsumetsu* discharge by 1.5 days. We also notice that the coefficients on admission are not significant for any *Rokuyo* except *Sensho*, which is marginally and negatively significant at the 10 percent level. However, as we discussed in detail earlier, the *Rokuyo* at admission is conceptually random because a patient cannot choose when he/she is affected by AMI and cannot wait to be hospitalized once an episode occurs. Elderly and male patients are more likely to have longer LOS, while LOS tends to be shorter if the patient has a spouse.

The F-value of the first stage is 12, which implies that the relevance of the instrument is still satisfied according to the Staiger–Stock rule of thumb ($F > 10$; Staiger and Stock, 1997). The reported Kleibergen–Paap Wald rank F statistic is 12.36, which again implies that weak identification is not to be considered a problem. Further, the Sargan–Hansen J statistic is 4.490 and its p-value is 0.8763. Thus, the joint null hypothesis that the instruments are valid and that the excluded instruments are correctly excluded from the estimated equation cannot be rejected.

Examining the coefficients in the second stage of the estimation, the coefficient on LOS is not statistically significant. In contrast to the results in Table 5 using OLS, this observation

[17] The full results are available on request from the authors.

indicates that the difference in LOS across discharge *Rokuyo* does not affect rehospitalization probability. While the gap in LOS between *Butsumetsu* (base case) and *Taian* is 1.5 days in the first stage, the coefficient on LOS in the second stage is not statistically significant. This result is not altered even in specification using two-step GMM or LIML.

In sum, while the association between LOS and rehospitalization is statistically significant in the OLS estimation, the coefficient of LOS is no longer significant once the endogeneity is corrected by using *Rokuyo* as an instrumental variable. In other words, additional stay caused by the choice of preferable *Rokuyo* at discharge (by patients) does not have a causal effect on treatment outcome.

4. Robustness checks

We conducted two types of robustness checks. The first one was using a different time window for rehospitalization. In the main specification, we specified that a patient is considered rehospitalized if he/she was rehospitalized (or passed away) within one year after discharge. However, this one-year time window is slightly arbitrary. We re-estimate the same model by changing this time window for rehospitalization to six months, nine months, and two years. In the second robustness check, we use the log of LOS. As depicted in Figure 2, the distribution of LOS is skewed to the right; thus, in alternative specifications, we use log(LOS) instead of LOS. Figure 3 illustrates the distribution of log(LOS), which is closer to a normal distribution than LOS itself.

Table 7 presents the results of these two robustness checks. The table reports the coefficient of LOS or log(LOS) in the second stage of the estimation. When log(LOS) is used, the results from the first stage of the estimation (not shown) are similar to those using LOS. In particular, the coefficient of *Taian* is positive and statistically significant. If the *Rokuyo* at discharge is *Taian*, the LOS is longer by 1.2 days than the LOS at discharge on *Butsumetsu*. Further, the F-value and Sargan–Hansen J statistic are 14.04 and 4.332 (P-value = 0.8882),

respectively, thereby implying that the instruments are valid.

The table shows that the OLS estimation consistently indicates a positive relationship between LOS (or log(LOS)) and probability of rehospitalization, regardless of the time window of rehospitalization. On the other hand, once instrumented, such a positive relationship loses its significance. There is only one case—time window of six months for rehospitalization estimated by two-step GMM using LOS—where the relationship is *negative* and very marginally significant at the 10 percent level. However, in all other cases in 2SLS, two-step GMM, and LIML, the coefficient of LOS or log(LOS) are insignificant. Therefore, these robustness checks broadly support our main results.

5. Conclusion

A long ALOS is one of the distinct characteristics of the Japanese medical care program. In this study, we carefully explored the causal relationship between LOS in hospitals and treatment outcome for AMI patients in Japan. We addressed the endogeneity between LOS and treatment outcome by using an exogenous variation in the *Rokuyo* days, which are found to be irrelevant to admission day but relevant to discharge day. While we did find a significant association between LOS and rehospitalization probability in the OLS estimation, we did not find a significant relationship once LOS is instrumented by the six basic labels in 2SLS, two-step GMM, and LIML estimations.

This implies that additional stay because of patient's choice of preferred *Rokuyo* at discharge has no effect on rehospitalization probability. In particular, our result shows that the gap in the ALOS for a patient discharged on a *Taian* day and for a patient discharged on a *Butsumetsu* day is 1.5 days and the difference has no effect on rehospitalization probability.

Our results suggest that there is room for improving efficiency in the use of medical resources. Whether a reduction in LOS contributes to reducing total medical costs depends not only on LOS but also on the supply of medical care services, including the number of beds as

well as density of physicians and nurses. A subject for further research could be the consideration of any possible change in hospital behavior to maintain the revenue specified under the fee-for-service program.

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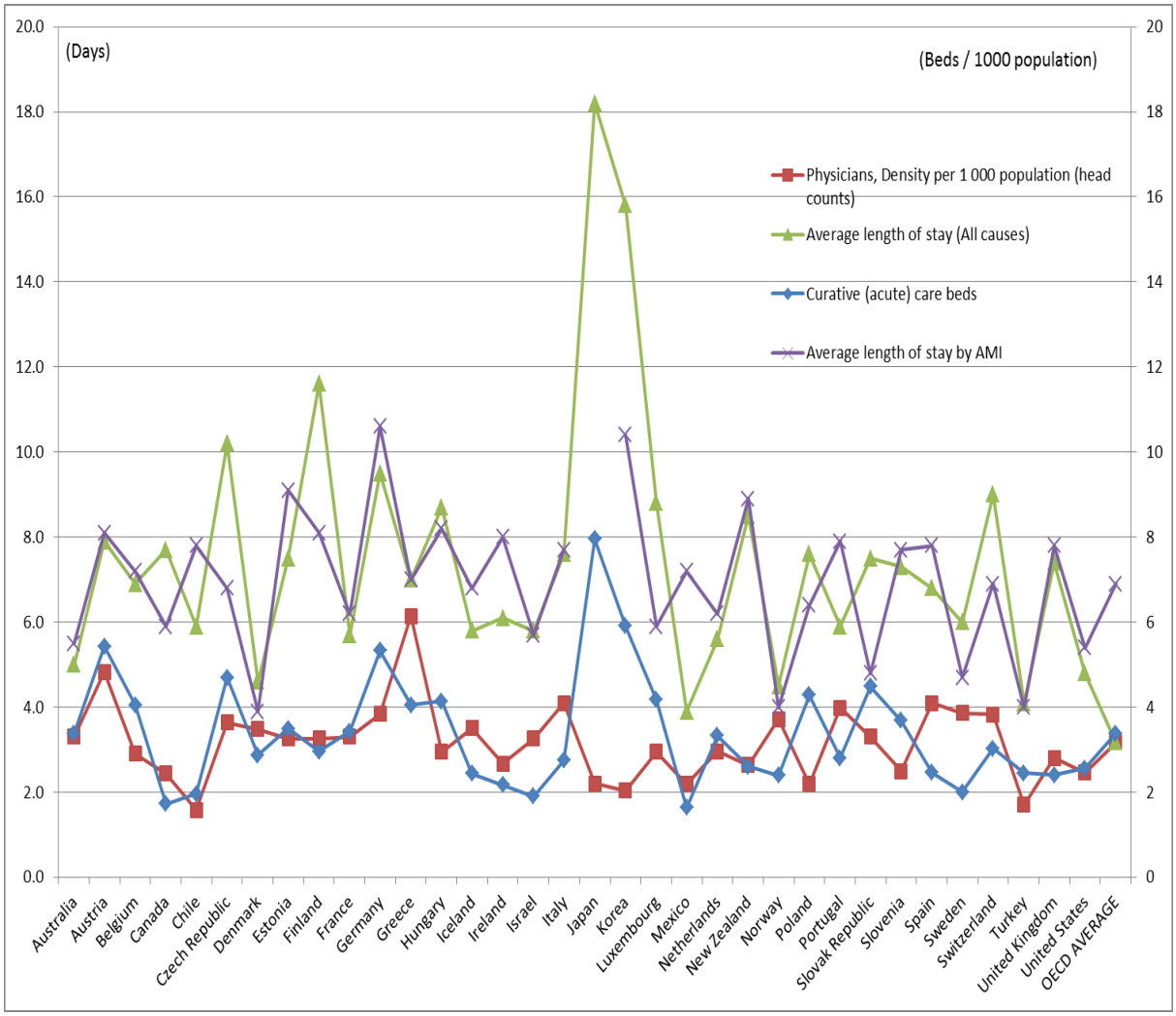
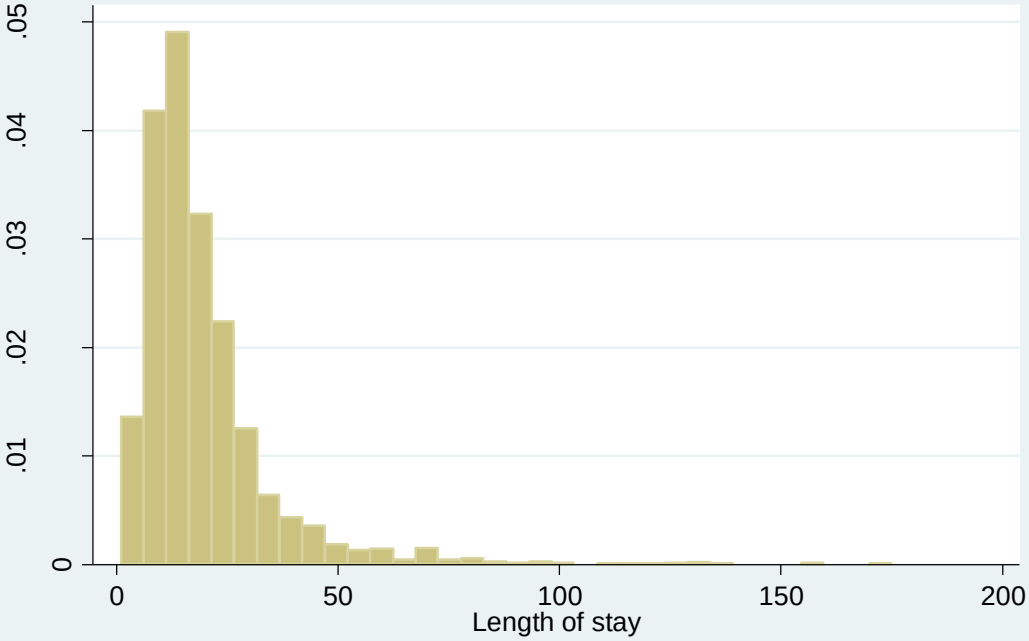
Figure 1 Average length of stay, curative care beds, and physician density among OECD countries



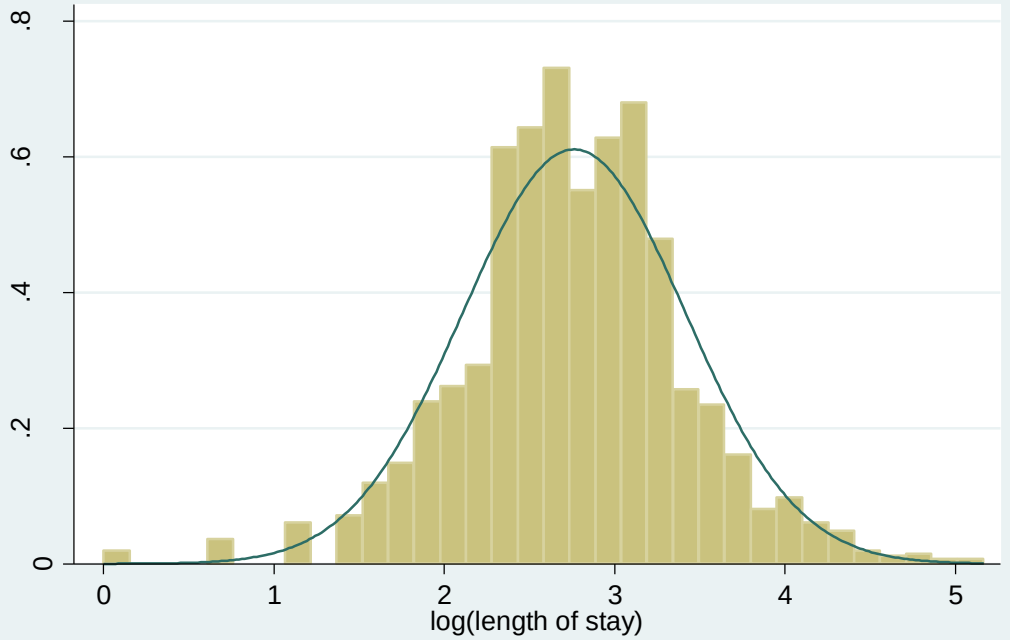
(Note) Data is taken from OECD Health Data 2013. The timing is 2011 or the closest year.

Figure 2: Length of Stay



Patients hospitalized for more than 180 days were excluded.

Figure 3: log(Length of Stay)



Patients hospitalized for more than 180 days were excluded.

Table 1: *Rokuyo* on admission and discharge days and the length of stay

	(1) Admission		(2) Length of stay		(3) Discharge		(4) Length of stay	
	Frequency	(%)	Average	S.D.	Frequency	(%)	Average	S.D.
Butsumetsu	545	16.87	20.31	16.99	390	13.26	18.85	15.54
Taian	549	16.99	20.77	18.29	646	21.96	21.18	15.88
Shakko	560	17.33	19.00	14.04	449	15.26	19.12	13.90
Sensho	516	15.97	18.85	14.13	518	17.61	18.87	14.20
Tomobiki	521	16.13	19.61	14.74	497	16.89	20.58	16.62
Senpu	540	16.71	20.16	15.45	442	15.02	18.46	13.18
Total	3231				2942			

(Note) The sample used to compute length of stay excludes patients hospitalized for more than 180 days.

Table2: Kolmogorov-Smirnov test for equality of distribution of length of stay by *Rokuyo* on admission and discharge days

Admission	*Butsumetsu*	*Taian*	*Shakko*	*Sensho*	*Tomobiki*
Taian	0.862				
Shakko	0.446	0.837			

Sensho	0.296	0.733	0.997		
Tomobiki	0.802	0.984	0.940	0.843	
Senpu	0.470	0.865	0.676	0.534	0.528

Discharge	*Butsumetsu*	*Taian*	*Shakko*	*Sensho*	*Tomobiki*
Taian	0.009***				
Shakko	0.772	0.139			
Sensho	0.969	0.041**	0.797		
Tomobiki	0.113	0.638	0.600	0.307	
Senpu	0.627	0.000***	0.244	0.313	0.029**

(Note)

1. The sample to compute length of stay excludes a patient who is hospitalized more than 180 days.

2. *** significant at 1 percent level, ** significant at 5 percent level

Table 3 Descriptive statistics (Individual demographics)

Variables	# obs	Mean	S.D.
dum1: re-hospitalization dummy (within 1 year, =1 if re-hospitalized)	2690	0.393	0.488
Age	2690	65.090	11.327
P_1: Sex (=1 if male)	2690	0.784	0.411
iins1: type of medical insurance (National Health Insurance)	2690	0.639	0.480
iins2: type of medical insurance (Employees Health / Mutual Assistance Insurance)	2690	0.161	0.367
iins3: type of medical insurance (no insurance, 100% OOP)	2690	0.013	0.112
iins4: type of medical insurance (Government-managed insurance)	2690	0.096	0.294
iins5: type of medical insurance (Public assistance)	2690	0.010	0.098
iins6: type of medical insurance (Health Insurance Society)	2690	0.083	0.276
fam: Number of family members living with a patient	2690	2.152	1.605
spouse: Presence of spouse (=1 if yes)	2690	0.775	0.417
days_h: LOS	2690	19.631	15.418
rok1_d: *Rokuyo* at discharge (*Butsumetsu*)	2690	0.135	0.341
rok2_d: *Rokuyo* at discharge (*Taian*)	2690	0.221	0.415
rok3_d: *Rokuyo* at discharge (*Shakko*)	2690	0.152	0.359
rok4_d: *Rokuyo* at discharge (*Sensho*)	2690	0.172	0.377
rok5_d: *Rokuyo* at discharge (*Tomobiki*)	2690	0.170	0.375
rok6_d: *Rokuyo* at discharge (*Senbu*)	2690	0.151	0.358
rok1_h: *Rokuyo* at admission (*Butsumetsu*)	2690	0.170	0.376
rok2_h: *Rokuyo* at admission (*Taian*)	2690	0.173	0.379
rok3_h: *Rokuyo* at admission (*Shakko*)	2690	0.171	0.377
rok4_h: *Rokuyo* at admission (*Sensho*)	2690	0.161	0.368
rok5_h: *Rokuyo* at admission (*Tomobiki*)	2690	0.161	0.368
rok6_h: *Rokuyo* at admission (*Senbu*)	2690	0.163	0.370
_IFA_1_2 : hospital 2 dummy	2690	0.041	0.197
_IFA_1_3 : hospital 3 dummy	2690	0.095	0.293
_IFA_1_4 : hospital 4 dummy	2690	0.113	0.316
_IFA_1_5 : hospital 5 dummy	2690	0.089	0.285
_IFA_1_6 : hospital 6 dummy	2690	0.025	0.157
_IFA_1_7 : hospital 7 dummy	2690	0.011	0.103
_IFA_1_8 : hospital 8 dummy	2690	0.032	0.177
_IFA_1_9 : hospital 9 dummy	2690	0.095	0.293
_IFA_1_10 : hospital 10 dummy	2690	0.038	0.192
_IFA_1_11 : hospital 11 dummy	2690	0.085	0.279
_IFA_1_12 : hospital 12 dummy	2690	0.036	0.186
_IFA_1_13 : hospital 13 dummy	2690	0.151	0.358
_IFA_1_14 : hospital 14 dummy	2690	0.024	0.154
_IFA_1_15 : hospital 15 dummy	2690	0.126	0.332

Table 4: Descriptive statistics (Comorbidity variables and severity variables at admission)

Variables	# obs	Mean	S.D.	Min	Max
(1) Comorbidity variables at admission					
uri1: Continence: totally continent	2960	0.983	0.130	0	1
uri2: Continence: occasionally incontinent	2960	0.010	0.102	0	1
uri3: Continence: no urine output	2960	0.001	0.039	0	1
uri4: Continence: unknown	2960	0.005	0.072	0	1
walk1: Mobility: Walks Independently	2960	0.966	0.181	0	1
walk2: Mobility: Walks with assistance	2960	0.022	0.146	0	1
walk3: Mobility: Unable to walk	2960	0.008	0.090	0	1
walk4: Mobility: unknown	2960	0.004	0.061	0	1
X_1y: Hypertension	2960	0.432	0.495	0	1
X_1d: Hypertension: unknown	2960	0.000	0.000	0	0
Y_1y: Hyperlipemia	2960	0.175	0.380	0	1
Y_1d: Hyperlipemia: unknown	2960	0.000	0.019	0	1
Z_1y: Diabetes（any type）	2960	0.278	0.448	0	1
Z_1d: Diabetes（any type）: unknown	2960	0.000	0.000	0	0
AA_1y: Diabetes treated by insulin	2960	0.038	0.191	0	1
AA_1d: Diabetes treated by insulin: unknown	2960	0.728	0.445	0	1
AB_1y: Angina	2960	0.123	0.329	0	1
AB_1d: Angina: unknown	2960	0.000	0.019	0	1
AD_1y: Cardiac heart failure or pulmonary edema	2960	0.030	0.172	0	1
AD_1d: Cardiac heart failure or pulmonary edema: unknown	2960	0.000	0.019	0	1
AF_1y: Old myocadial infarction	2960	0.098	0.297	0	1
AF_1d: Old myocadial infarction: unknown	2960	0.000	0.000	0	0
AH_1y: Current cigarette smoker	2960	0.533	0.499	0	1
AH_1d: Current cigarette smoker: unknown	2960	0.001	0.033	0	1
AJ_1y: Arrhythmia	2960	0.054	0.225	0	1
AJ_1d: Arrhythmia: unknown	2960	0.000	0.019	0	1
AK_1y: Family medical history of schemic heart disease	2960	0.087	0.282	0	1
AK_1d: Family medical history of schemic heart disease: unknown	2960	0.000	0.019	0	1
AL_1y: Renal failure	2960	0.019	0.136	0	1
AL_1d: Renal failure: unknown	2960	0.000	0.000	0	0
AM_1y: Cirrhosis	2960	0.004	0.061	0	1
AM_1d: Cirrhosis: unknown	2960	0.000	0.019	0	1
AN_1y: Cerebrovascular accident: Cerebral infarction	2960	0.090	0.286	0	1
AN_1d: Cerebrovascular accident: Cerebral infarction: unknown	2960	0.000	0.000	0	0
AO_1y: Cerebrovascular accident: Brain hemorrhage	2960	0.012	0.108	0	1
AO_1d: Cerebrovascular accident: Brain hemorrhage: unknown	2960	0.007	0.086	0	1
AP_1y: Cerebrovascular accident: Subarachnoid hemorrhage	2960	0.006	0.074	0	1
AP_1d: Cerebrovascular accident: Subarachnoid hemorrhage: unknown	2960	0.007	0.084	0	1
AQ_1y: COPD	2960	0.010	0.102	0	1
AQ_1d: COPD: unknown	2960	0.000	0.000	0	0
AR_1y: Aneurysm of aorta	2960	0.012	0.107	0	1
AR_1d: Aneurysm of aorta: unknown	2960	0.000	0.000	0	0
AS_1y: Ulcus pepticum	2960	0.094	0.292	0	1
AS_1d: Ulcus pepticum: unknown	2960	0.000	0.000	0	0
AT_1y: Cancer	2960	0.044	0.206	0	1
AT_1d: Cancer: unknown	2960	0.000	0.000	0	0
AU_1y: Autoimmune disease	2960	0.017	0.130	0	1
AU_1d: Autoimmune disease: unknown	2960	0.000	0.000	0	0
AV_1y: Drug allergy/med reaction	2960	0.053	0.224	0	1
AV_1d: Drug allergy/med reaction: unknown	2960	0.000	0.000	0	0
AW_1y: Dementia/alzheimer's disease	2960	0.017	0.128	0	1
AW_1d: Dementia/alzheimer's disease: unknown	2960	0.000	0.000	0	0
AX_1y: Terminal illness	2960	0.001	0.039	0	1
AX_1d: Terminal illness: unknown	2960	0.000	0.019	0	1
AY_1y: CAG history	2960	0.126	0.332	0	1
AY_1d: CAG history: unknown	2960	0.000	0.019	0	1
AZ_1y: PTCA history	2960	0.086	0.280	0	1
AZ_1d: PTCA history:unknown	2960	0.000	0.019	0	1
BA_1y: CABG history	2960	0.010	0.102	0	1
BA_1d: CABG history: unknown	2960	0.000	0.019	0	1
(2) Severerity variables at admission					
Heart rate					
admspls0: =1 if heart rate < 60	2960	0.102	0.303	0	1
admspls1: =1 if 60 <= heart rate < 80	2960	0.417	0.493	0	1
admspls2: =1 if 80 <= heart rate < 100	2960	0.351	0.477	0	1
admspls3: =1 if 100 <= heart rate < 120	2960	0.094	0.292	0	1
admspls4: =1 if 120 <= heart rate < 150	2960	0.023	0.151	0	1
admspls5: =1 if 150 <= heart rate	2960	0.002	0.047	0	1
admspls_y: =1 if heart rate unknown	2960	0.010	0.098	0	1
Temperature					
admtmp1: =1 if temperature > 38.3	2960	0.002	0.047	0	1
admtmp2: =1 if 35.8 <= temperature < 38.3	2960	0.726	0.446	0	1
admtmp3: =1 if temperature < 35.8	2960	0.191	0.394	0	1
admtmp_y: =1 if temperature unknown	2960	0.081	0.272	0	1

Table 4 (continued): Descriptive statistics (Comorbidity variables and severity variables at admission)

Variables	# obs	Mean	S.D.	Min	Max
MAP(mean arterial pressure)					
map0: =1 if MAP < 60	2960	0.019	0.138	0	1
map1: =1 if 60 <= MAP < 80	2960	0.205	0.404	0	1
map2: =1 if 80 <= MAP < 100	2960	0.411	0.492	0	1
map3: =1 if 100 <= MAP < 120	2960	0.236	0.425	0	1
map4: =1 if 120 <= MAP < 150	2960	0.062	0.241	0	1
map5: =1 if 150 <= MAP	2960	0.003	0.058	0	1
map_y: =1 if MAP unknown	2960	0.063	0.243	0	1
Height (cm)					
hei0: =1 if hei < 140	2960	0.007	0.082	0	1
hei1: =1 if 140 <= hei < 150	2960	0.076	0.265	0	1
hei2: =1 if 150 <= hei < 160	2960	0.200	0.400	0	1
hei3: =1 if 160 <= hei < 170	2960	0.374	0.484	0	1
hei4: =1 if 170 <= hei < 180	2960	0.142	0.350	0	1
hei5: =1 if 180 <= hei	2960	0.006	0.074	0	1
hei_y: =1 if height unknown	2960	0.195	0.396	0	1
Weight (kg)					
wei0: =1 if wei < 40	2960	0.019	0.136	0	1
wei1: =1 if 40 <= wei < 50	2960	0.100	0.301	0	1
wei2: =1 if 50 <= wei < 60	2960	0.230	0.421	0	1
wei3: =1 if 60 <= wei < 70	2960	0.261	0.439	0	1
wei4: =1 if 70 <= wei < 80	2960	0.138	0.345	0	1
wei5: =1 if 80 <= wei < 90	2960	0.045	0.206	0	1
wei6: =1 if 90 <= wei	2960	0.017	0.131	0	1
wei_y: =1 if weight unknown	2960	0.000	0.000	0	0
BMI					
bmi0: =1 if bmi < 18.5	2960	0.047	0.212	0	1
bmi1: =1 if 18.5 <= bmi < 25	2960	0.500	0.500	0	1
bmi2: =1 if 25 <= bmi < 30	2960	0.213	0.409	0	1
bmi3: =1 if 30 <= bmi	2960	0.030	0.170	0	1
bmi_y: =1 if BMI unknown	2960	0.211	0.408	0	1
Glucose					
admglu0: =1 if admglu < 50	2960	0.002	0.043	0	1
admglu1: =1 if 50 <= admglu < 250	2960	0.833	0.373	0	1
admglu2: =1 if 250 <= admglu < 400	2960	0.104	0.305	0	1
admglu3: =1 if 400 <= admglu < 600	2960	0.014	0.120	0	1
admglu4: =1 if 600 <= admglu	2960	0.001	0.033	0	1
admglu_y: =1 if Glucose unknown	2960	0.046	0.209	0	1
Albumin					
admalb0: =1 if admalb < 2	2960	0.003	0.058	0	1
admalb1: =1 if 2 <= admalb < 5	2960	0.845	0.362	0	1
admalb2: =1 if 5 <= admalb	2960	0.016	0.124	0	1
admalb_y: =1 if Albumin unknown	2960	0.136	0.343	0	1
Highest creatinine					
admlcre9_1y: =1 if Highest creatinine >= 25	2960	0.001	0.027	0	1
admlcre9_1d: Highest creatinine unknown	2960	0.034	0.182	0	1
Hematocrit					
admhemac0: =1 if admhemac < 20	2960	0.006	0.074	0	1
admhemac1: =1 if 20 <= admhemac < 25	2960	0.010	0.098	0	1
admhemac2: =1 if 25 <= admhemac < 30	2960	0.035	0.185	0	1
admhemac3: =1 if 30 <= admhemac < 35	2960	0.151	0.358	0	1
admhemac4: =1 if 35 <= admhemac < 55	2960	0.776	0.417	0	1
admhemac5: =1 if 55<= admhemac	2960	0.003	0.058	0	1
admhemac_y: =1 if Hematocrit unknown	2960	0.019	0.136	0	1
White blood cells (unit:000)					
admwbc0: =1 if admwbc < 1000	2960	0.000	0.019	0	1
admwbc1: =1 if 1000 <= admwbc < 15000	2960	0.899	0.301	0	1
admwbc2: =1 if 15000 <= admwbc	2960	0.094	0.292	0	1
admwbc_y: =1 if White blood cells unknown	2960	0.006	0.079	0	1
Platelets (unit:0000)					
admlplt0: =1 if admlplt < 20	2960	0.425	0.494	0	1
admlplt1: =1 if 20 <= admlplt < 100	2960	0.557	0.497	0	1
admlplt2: =1 if 100 <= admlplt < 500	2960	0.012	0.108	0	1
admlplt3: =1 if 500 <= admlplt	2960	0.000	0.000	0	0
admlplt_y: =1 if Platelets unknown	2960	0.006	0.079	0	1
Blood urea nitrogen					
bunsun0: =1 if bunsun < 10	2960	0.069	0.254	0	1
bunsun1: =1 if 10 <= bunsun < 20	2960	0.681	0.466	0	1
bunsun2: =1 if 20 <= bunsun < 30	2960	0.182	0.386	0	1
bunsun3: =1 if 30 <= bunsun	2960	0.058	0.234	0	1
bunsun_y: =1 if Blood urea nitrogen unknown	2960	0.010	0.100	0	1
CH_1y: EKG trace: MI /injury (excluding old MI)	2960	0.896	0.305	0	1
CH_1d: EKG trace: MI /injury (excluding old MI): unknown	2960	0.000	0.000	0	0
CJ_1y: EKG trace: transmural (new qwave) MI	2960	0.174	0.379	0	1
CJ_1d: EKG trace: transmural (new qwave) MI: unknown	2960	0.271	0.445	0	1
CK_1y: EKG trace: old/remote MI	2960	0.041	0.198	0	1
CK_1d: EKG trace: old/remote MI: unknown	2960	0.000	0.019	0	1
CL_1y: EKG trace: ventricular tachycardia/flutter	2960	0.154	0.361	0	1
CL_1d: EKG trace: ventricular tachycardia/flutter: unknown	2960	0.001	0.027	0	1
CM_1y: EKG trace: atrial fibrillation/flutter	2960	0.089	0.285	0	1
CM_1d: EKG trace: atrial fibrillation/flutter: unknown	2960	0.001	0.027	0	1
CN_1y: EKG trace: LBBB	2960	0.014	0.120	0	1
CN_1d: EKG trace: LBBB: unknown	2960	0.001	0.027	0	1
CO_1y: EKG trace: RBBB	2960	0.059	0.235	0	1
CO_1d: EKG trace: RBBB: unknown	2960	0.001	0.027	0	1
CP_1y: EKG trace: left fascicular blocks	2960	0.010	0.098	0	1
CP_1d: EKG trace: left fascicular blocks: unknown	2960	0.001	0.033	0	1
CQ_1y: EKG trace: heart block, 2nd/3rd degree	2960	0.055	0.229	0	1
CQ_1d: EKG trace: heart block, 2nd/3rd degree: unknown	2960	0.001	0.027	0	1
CS_1y: CHF (congestive heart failure) /pulmonary edema on chest X rays	2960	0.220	0.414	0	1
CS_1d: CHF (congestive heart failure) /pulmonary edema on chest X rays: unknown	2960	0.002	0.043	0	1
CW_1y: Stress test suggests ischemia	2960	0.011	0.105	0	1
CW_1d: Stress test suggests ischemia: unknown	2960	0.846	0.361	0	1

Table 5: OLS estimation using *Rokuyo*

	Column (1)			Column (2)		
Dependent variable: Rehospitalization dummy (within 1 year, =1 if rehospitalized)	coefficient	S.E.		coefficient	S.E.	
(A) Individual demograraphics						
days_h: LOS	0.0031	0.0009	***	0.0024	0.0008	***
Age	0.0014	0.0011		0.0012	0.0012	
P_1: Sex (=1 if male)	-0.0267	0.0220		-0.0158	0.0272	
iins1: type of medical insurance (National Health Insurance) [base case]	-	-				
iins2: type of medical insurance (Employees Health / Mutual Assistance Insurance)	-0.0003	0.0212		-0.0022	0.0261	
iins3: type of medical insurance (no insurance, 100% OOP)	-0.0771	0.0871		-0.0425	0.0901	
iins4: type of medical insurance (Government-managed insurance)	-0.0357	0.0400	**	-0.0260	0.0403	
iins5: type of medical insurance (Public assistance)	0.0344	0.0954		0.0508	0.0807	
iins6: type of medical insurance (Health Insurance Society)	-0.0216	0.0303	***	-0.0207	0.0338	
fam: Number of family members living with a patient	0.0047	0.0032		0.0048	0.0034	
spouse: Presence of spouse (=1 if yes)	0.0272	0.0188		0.0199	0.0196	
_IFA_1_1 : hospital 1 dummy [base sase]	-	-		-	-	
_IFA_1_2 : hospital 2 dummy	-0.3799	0.0113	***	-0.3308	0.0250	***
_IFA_1_3 : hospital 3 dummy	-0.2107	0.0123	***	-0.1671	0.0217	***
_IFA_1_4 : hospital 4 dummy	-0.0256	0.0122	**	-0.0388	0.0167	**
_IFA_1_5 : hospital 5 dummy	-0.5599	0.0129	***	-0.4836	0.0413	***
_IFA_1_6 : hospital 6 dummy	-0.0637	0.0088	***	-0.0508	0.0200	**
_IFA_1_7 : hospital 7 dummy	-0.0750	0.0130	***	-0.0708	0.0252	***
_IFA_1_8 : hospital 8 dummy	-0.3816	0.0099	***	-0.4089	0.0294	***
_IFA_1_9 : hospital 9 dummy	-0.4539	0.0128	***	-0.4244	0.0266	***
_IFA_1_10 : hospital 10 dummy	-0.3025	0.0068	***	-0.3085	0.0291	***
_IFA_1_11 : hospital 11 dummy	-0.6407	0.0104	***	-0.6033	0.0281	***
_IFA_1_12 : hospital 12 dummy	-0.3498	0.0097	***	-0.2941	0.0264	***
_IFA_1_13 : hospital 13 dummy	-0.5702	0.0113	***	-0.5765	0.0174	***
_IFA_1_14 : hospital 14 dummy	-0.6730	0.0165	***	-0.6687	0.0272	***
_IFA_1_15 : hospital 15 dummy	-0.5034	0.0085	***	-0.5023	0.0191	***
(B) Cormobidity variables at admission						
uri1: Continence: totally continent				0.0885	0.2871	
uri2: Continence: occasionally incontinent				0.0913	0.3362	
uri3: Continence: no urine output				-	-	
uri4: Continence: unknown				0.1207	0.3167	
walk1: Mobility: Walks Independently				0.1300	0.0726	*
walk2: Mobility: Walks with assistance				0.0310	0.0783	
walk3: Mobility: Unable to walk				-	-	
walk4: Mobility: unknown				0.0282	0.1490	
X_1y: Hypertension				0.0496	0.0129	***
X_1d: Hypertension: unknown				-	-	
Y_1y: Hyperlipemia				0.0371	0.0262	
Y_1d: Hyperlipemia: unknown				-0.3261	0.1013	***
Z_1y: Diabetes（any type）				-0.0635	0.0658	
Z_1d: Diabetes（any type）: unknown				-	-	
AA_1y: Diabetes treated by insulin				-0.0011	0.0656	
AA_1d: Diabetes treated by insulin: unknown				-0.0957	0.0727	
AB_1y: Angina				0.0625	0.0263	**
AB_1d: Angina: unknown				0.9595	0.0702	***
AD_1y: Cardiac heart failure or pulmonary edema				0.0697	0.0823	
AD_1d: Cardiac heart failure or pulmonary edema: unknown				-0.3111	0.1178	***
AF_1y: Old myocadial infarction				0.0203	0.0423	
AF_1d: Old myocadial infarction: unknown				-	-	
AH_1y: Current cigarette smoker				-0.0174	0.0112	
AH_1d: Current cigarette smoker: unknown				0.0612	0.0880	
AJ_1y: Arrhythmia				-0.0320	0.0353	
AJ_1d: Arrhythmia: unknown				0.4061	0.0781	***
AK_1y: Family medical history of schemic heart disease				0.0456	0.0264	*
AK_1d: Family medical history of schemic heart disease: unknown				-0.2400	0.0620	***
AL_1y: Renal failure				-0.1552	0.0714	**
AL_1d: Renal failure: unknown				-	-	
AM_1y: Cirrhosis				-0.0044	0.1490	
AM_1d: Cirrhosis: unknown				-0.2624	0.0904	***
AN_1y: Cerebrovascular accident: Cerebral infarction				0.0073	0.0327	
AN_1d: Cerebrovascular accident: Cerebral infarction: unknown				-	-	
AO_1y: Cerebrovascular accident: Brain hemorrhage				0.1708	0.1136	
AO_1d: Cerebrovascular accident: Brain hemorrhage: unknown				-0.2373	0.0994	**
AP_1y: Cerebrovascular accident: Subarachnoid hemorrhage				-0.1122	0.0436	**
AP_1d: Cerebrovascular accident: Subarachnoid hemorrhage: unknown				0.3670	0.0971	***
AQ_1y: COPD				-0.0051	0.0746	
AQ_1d: COPD: unknown				-	-	
AR_1y: Aneurysm of aorta				0.0465	0.0716	
AR_1d: Aneurysm of aorta: unknown				-	-	
AS_1y: Ulcus pepticum				0.0073	0.0280	
AS_1d: Ulcus pepticum: unknown				-	-	
AT_1y: Cancer				0.0746	0.0586	
AT_1d: Cancer: unknown				-	-	
AU_1y: Autoimmune disease				0.0428	0.0933	
AU_1d: Autoimmune disease: unknown				-	-	
AV_1y: Drug allergy/med reaction				0.0154	0.0444	
AV_1d: Drug allergy/med reaction: unknown				-	-	
AW_1y: Dementia/alzheimer's disease				-0.1609	0.0601	***
AW_1d: Dementia/alzheimer's disease: unknown				-	-	
AX_1y: Terminal illness				0.3441	0.0722	***
AX_1d: Terminal illness: unknown				-0.1664	0.1544	
AY_1y: CAG history				-0.1071	0.0379	***
AY_1d: CAG history: unknown				-	-	
AZ_1y: PTCA history				0.0919	0.0509	*
AZ_1d: PTCA history:unknown				-	-	
BA_1y: CABG history				0.1637	0.0769	**
BA_1d: CABG history: unknown				-	-	

Table 5 (continued): OLS estimation using *Rokuyo*						
Dependent variable: Rehospitalization dummy (within 1 year, =1 if rehospitalized)	coefficient	S.E.		coefficient	S.E.	
(C) Sererity variables on admission						
Heart rate						
admspls0: =1 if heart rate<60				-0.0835	0.0504	*
admspls1: =1 if 60<=heart rate<80				-0.1111	0.0355	***
admspls2: =1 if 80<=heart rate<100				-0.1305	0.0361	***
admspls3: =1 if 100<=heart rate<120				-0.1242	0.0450	***
admspls4: =1 if 120<=heart rate<150				-0.0799	0.0574	
admspls5: =1 if 150<=heart rate				0.0804	0.2813	
admspls_y: =1 if heart rate unknown				-	-	
Temperature						
admtmp1: =1 if temperature>38.3				-	-	
admtmp2: =1 if 35.8<=temperature<38.3				-0.0521	0.1536	
admtmp3: =1 if temperature<35.8				-0.0557	0.1538	
admtmp_y: =1 if temperature unknown				-0.0046	0.1485	
MAP(mean arterial pressure)						
map0: =1 if MAP<60				-	-	
map1: =1 if 60<=MAP<80				0.1286	0.0837	
map2: =1 if 80<=MAP<100				0.1448	0.0887	
map3: =1 if 100<=MAP<120				0.1179	0.0950	
map4: =1 if 120<=MAP<150				0.1218	0.0787	
map5: =1 if 150<=MAP				0.4019	0.1611	**
map_y: =1 if MAP unknown				0.0544	0.0926	
Hight (cm)						
hei0: =1 if hei<140				0.0104	0.1946	
hei1: =1 if 140<=hei<150				0.1247	0.0962	
hei2: =1 if 150<=hei<160				0.1518	0.0710	**
hei3: =1 if 160<=hei<170				0.1399	0.0739	*
hei4: =1 if 170<=hei<180				0.1290	0.0798	
hei5: =1 if 180<=hei				-	-	
hei_y: =1 if height unknown				0.0699	0.0702	
Weight (kg)						
wei0: =1 if wei<40				0.1800	0.0963	*
wei1: =1 if 40<=wei<50				0.1412	0.0664	**
wei2: =1 if 50<=wei<60				0.1304	0.0638	**
wei3: =1 if 60<=wei<70				0.1213	0.0734	*
wei4: =1 if 70<=wei<80				0.1134	0.0862	
wei5: =1 if 80<=wei<90				0.0725	0.1151	
wei6: =1 if 90<=wei				0.0946	0.1294	
wei_y: =1 if weight unknown				-	-	
BMI						
bmi0: =1 if bmi<18.5				-0.1220	0.1350	
bmi1: =1 if 18.5<=bmi<25				-0.0758	0.0750	
bmi2: =1 if 25<=bmi<30				-0.0674	0.0625	
bmi3: =1 if 30<=bmi				-	-	
bmi_y: =1 if BMI unknown				0.0713	0.1483	
Glucose						
admglu0: =1 if admglu<50				-	-	
admglu1: =1 if 50<=admglu<250				-0.1164	0.1549	
admglu2: =1 if 250<=admglu<400				-0.0513	0.1465	
admglu3: =1 if 400<=admglu<600				-0.1816	0.1586	
admglu4: =1 if 600<=admglu				0.2967	0.2477	
admglu_y: =1 if Glucose unknown				-0.1318	0.1571	
Albumin						
admalb0: =1 if admalb<2				-	-	
admalb1: =1 if 2<=admalb<5				0.0522	0.1906	
admalb2: =1 if 5<=admalb				0.0317	0.1878	
admalb_y: =1 if Albumin unknown				0.1007	0.1940	
Highest creatinine						
admlcre9_1y: =1 if Highest creatinine>=25				0.0462	0.3265	
admlcre9_1d: Highest creatinine unknown				-0.0262	0.0585	
Hematocrit						
admhemac0: =1 if admhemac<20				-0.0134	0.1813	
admhemac1: =1 if 20<=admhemac<25				-0.1672	0.1037	
admhemac2: =1 if 25<=admhemac<30				-0.0720	0.1193	
admhemac3: =1 if 30<=admhemac<35				-0.0797	0.1047	
admhemac4: =1 if 35<=admhemac<55				-0.0523	0.0910	
admhemac5: =1 if 55<=admhemac				-	-	
admhemac_y: =1 if Hematocrit unknown				0.0155	0.1422	
White blood cells (unit:000)						
admwbc0: =1 if admwbc<1000				-	-	
admwbc1: =1 if 1000<=admwbc<15000				0.4536	0.1118	***
admwbc2: =1 if 15000<=admwbc				0.4819	0.1237	***
admwbc_y: =1 if White blood cells unknown				0.2952	0.1116	***
Platelets (unit:0000)						
admplt0: =1 if admplt<20				0.1514	0.1138	
admplt1: =1 if 20<=admplt<100				0.1470	0.1086	
admplt2: =1 if 100<=admplt<500				0.0127	0.1130	
admplt3: =1 if 500<=admplt				-	-	
admplt_y: =1 if Platelets unknown				-	-	
Blood urea nitrogen						
bunsun0: =1 if bunsun<10				-	-	
bunsun1: =1 if 10<=bunsun<20				0.0565	0.0233	**
bunsun2: =1 if 20<=bunsun<30				0.0323	0.0235	
bunsun3: =1 if 30<=bunsun				0.1119	0.0754	
bunsun_y: =1 if Blood urea nitrogen unknown				0.0569	0.0866	
CH_1y: EKG trace: MI /injury (excluding old MI)				0.0382	0.0305	
CH_1d: EKG trace: MI /injury (excluding old MI): unknown				-	-	
CJ_1y: EKG trace: transmural (new qwave) MI				-0.0040	0.0245	
CJ_1d: EKG trace: transmural (new qwave) MI: unknown				0.0289	0.0373	
CK_1y: EKG trace: old/remote MI				0.0017	0.0558	
CK_1d: EKG trace: old/remote MI: unknown				-0.4338	0.0940	***
CL_1y: EKG trace: ventricular tachycardia/flutter				0.0151	0.0257	
CL_1d: EKG trace: ventricular tachycardia/flutter: unknown				0.9343	0.0988	***
CM_1y: EKG trace: atrial fibrillation/flutter				-0.0590	0.0345	*
CM_1d: EKG trace: atrial fibrillation/flutter: unknown				-	-	
CN_1y: EKG trace: LBBB				0.0230	0.0620	
CN_1d: EKG trace: LBBB: unknown				-	-	
CO_1y: EKG trace: RBBB				0.0417	0.0340	
CO_1d: EKG trace: RBBB: unknown				0.0000	(omitted)	
CP_1y: EKG trace: left fascicular blocks				-0.0712	0.0744	
CP_1d: EKG trace: left fascicular blocks: unknown				-0.2730	0.0796	***
CQ_1y: EKG trace: heart block, 2nd/3rd degree				-0.0202	0.0318	
CQ_1d: EKG trace: heart block, 2nd/3rd degree: unknown				-	-	
CS_1y: CHF (congestive heart failure) /pulmonary edema on chest X rays				0.0619	0.0248	**
CS_1d: CHF (congestive heart failure) /pulmonary edema on chest X rays: unknown				-0.4512	0.0229	***
CW_1y: Stress test suggests ischemia				0.0129	0.0489	
CW_1d: Stress test suggests ischemia: unknown				0.0615	0.0308	**
Constant	0.6223	0.0752	***	-0.3276	0.5090	
R-squared	0.2029			0.2520		
Number of observations	2690			2690		
(Note) ***, **, and * indicate significance at the 1%, 5% and 10% levels.						

Table 6: 2SLS, 2-Step GMM, and LIML estimation using *Rokuyo*

	Specification (1)						Specification (2)			Sprcification (3)		
	2SLS						Two step GMM			LIML		
	First stage			Second stage			Second stage			Second stage		
	Coefficient	S.E.		Coefficient	S.E.		Coefficient	S.E.		Coefficient	S.E.	
days_h: LOS	-	-		0.0058	0.0080		0.004	0.015		0.0023	0.0131	
Age	0.0550	0.0274	**	0.0009	0.0017	***	0.001	0.001		0.0012	0.0013	
P_1: Sex (=1 if male)	2.3516	0.5277	***	-0.0286	0.0236		-0.020	0.056		-0.0155	0.0470	
iins1: type of medical insurance (National Health Insurance) [base case]	-	-		-	-		-	-		-	-	
iins2: type of medical insurance (Employees Health / Mutual Assistance Insurance)	0.0338	0.5979		0.0025	0.0170		-	-		-0.0022	0.0248	
iins3: type of medical insurance (no insurance, 100% OOP)	-2.7166	2.3065		-0.0730	0.0819		-	-		-0.0428	0.0927	
iins4: type of medical insurance (Government-managed insurance)	-2.2318	1.1688		-0.0267	0.0361	**	-	-		-0.0262	0.0398	
iins5: type of medical insurance (Public assistance)	4.9694	2.3074	**	0.0149	0.0922		-	-		0.0515	0.0966	
iins6: type of medical insurance (Health Insurance Society)	-0.7949	1.2016		-0.0189	0.0271	***	-	-		-0.0208	0.0298	
fam: Number of family members living with a patient	-0.2399	0.1532		0.0053	0.0034		0.005	0.004		0.0047	0.0052	
spouse: Presence of spouse (=1 if yes)	-2.3047	0.8644	***	0.0350	0.0277		0.024	0.032		0.0196	0.0344	
rok1_d: *Rokuyo* at discharge (*Butsumetsu*)	-	-		-	-							
rok2_d: *Rokuyo* at discharge (*Taian*)	1.5477	0.7480	**	-	-		-	-				
rok3_d: *Rokuyo* at discharge (*Shakko*)	-0.0844	1.1907		-	-		-	-				
rok4_d: *Rokuyo* at discharge (*Sensho*)	0.8670	1.1458		-	-		-	-				
rok5_d: *Rokuyo* at discharge (*Tomobiki*)	0.3916	0.7717		-	-		-	-				
rok6_d: *Rokuyo* at discharge (*Senbu*)	0.3095	0.6779		-	-		-	-				
rok1_h: *Rokuyo* at admission (*Butsumetsu*)	-	-		-	-		-	-				
rok2_h: *Rokuyo* at admission (*Taian*)	0.0520	1.1098		-	-		-	-				
rok3_h: *Rokuyo* at admission (*Shakko*)	-1.8235	1.0951		-	-		-	-				
rok4_h: *Rokuyo* at admission (*Sensho*)	-1.4883	0.7869	*	-	-		-	-				
rok5_h: *Rokuyo* at admission (*Tomobiki*)	-1.1554	0.8582		-	-		-	-				
rok6_h: *Rokuyo* at admission (*Senbu*)	-0.5031	0.8704		-	-		-	-				
Constant	19.2471	11.1911		0.750	0.213	***	-	-		0.3514	0.3662	
R-squared	0.3041											
F value	12.00											
Kleibergen-Paap Wald rk F statistic	12.36											
Sargan-Hansen J statistic [P-value]	4.490 [0.8763]											
Number of observations	2690			2690			2690			2690		

(Note)

1: Standard errors are clustered at health facility level. ***, **, and * indicate significance of the 1%, 5%, and 10% levels.

2: In all the specifications, comorbidity variables at admission, severity variables at admission, and health facility level fixed effect are included.

Table 7: Robustness checks

		OLS			2SLS		Two step GMM			LIML	
Length of stay	Time-window of rehospitalization	Coefficient	S.E.		Coefficient	S.E.	Coefficient	S.E.		Coefficient	S.E.
LOS	6 months	0.0021	0.0007	***	-0.0008	0.0076	-0.0083	0.0048	*	-0.0036	0.0145
	9 months	0.0019	0.0008	**	-0.0013	0.0081	-0.0030	0.0046		-0.0025	0.0112
	1 year	0.0024	0.0008	***	0.0058	0.0080	0.0043	0.0154		0.0023	0.0131
	2 years	0.0020	0.0009	**	0.0063	0.0086	0.0111	0.0069		0.0079	0.0120
log(LOS)	6 months	0.0699	0.0179	***	0.0767	0.1932	0.1331	0.1200		0.0808	0.3091
	9 months	0.0705	0.0208	***	0.0082	0.1689	-0.0166	0.1218		-0.0094	0.2171
	1 year	0.0761	0.0202	***	0.0739	0.1831	-0.0176	0.1283		0.0733	0.2382
	2 years	0.0689	0.0228	***	0.1414	0.2137	0.1090	0.1615		0.1614	0.2707

(Note) ***, **, and * indicate significance of the 1%, 5%, and 10% levels.