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Abstract

The aim of this study is to examine the relationship between the competition between hospitals in Japan and the investment in specialists and advanced medical technologies, which are a major determinant of costs and quality in health care. We focus the analysis on the adoption of computed tomography (CT) and magnetic resonance imaging (MRI) scanners, as well as on the number of full-time radiologists working in each medical institution. Hospitals are evaluated based on the total availability of services, including both radiologists and cutting-edge imaging equipment, rather than on the availability of individual services. Therefore, in this study, we measure the adoption of advanced imaging technologies at both the aggregate and the single-technology levels. Based on an instrumental variable approach, we find that competition is positively correlated to the overall adoption of advanced imaging technologies, higher performance CT scanners, and to the number of radiologists. Additionally, we examine whether this relationship varies with governance structure of hospitals. The results suggest that private hospitals are particularly sensitive to competition in comparison to non-private hospitals.

Keywords: Hospital competition; Medical technology; Technology diffusion; Hospital ownership

JEL classification: I11, I18

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1. Introduction

In the health care sector, due to the presence of both information asymmetries and insurance, competition may not necessarily lead to the reduction of costs and inefficiency [1]. Indeed, the empirical evidence provides mixed results in this respect. Early research highlighted that a competitive environment brought about higher costs for US hospitals [2]. Competition may nourish the so-called medical arms race (MAR); that is, hospitals in competitive markets may adopt advanced medical technologies to attract patients and physicians, which, in turn, leads to higher costs. Although it was found that, in the 1990s, competition contributed to lowering costs through the increase in health maintenance organization enrollment, which slowed the diffusion of medical technologies [3-4], some recent studies suggest the re-emergence of the MAR [5-7]. As the advancements in medical technology are considered to be a major driver of the growth of health care expenditures [8], improving our understanding of the relationship between hospitals' competition and the adoption of advanced medical technologies is of particular importance.

More specifically, we aim to examine whether competition can be associated with the adoption of imaging technologies, more specifically computed-tomography (CT) scanners, magnetic resonance imaging (MRI) scanners, as well as with the number of radiologists in the medical institution. Our study contributes to the existing literature in three respects. First, by using detailed information from a survey of all hospitals in Japan, we provided an accurate measure for the adoption of imaging technologies. Indeed, most studies simply focus on whether medical institutions adopt certain medical technologies while neglecting to look at how advanced are such technologies. The costs and the quality of images of single-detector CT, for example, are quite different from those of multi-detector CT. In this context, not accounting for the differences in the progress level of each adopted technology becomes problematic. To address this issue, in this study we distinguished both CT and MRI scanners by their progress level. In addition, previous research on MAR did not consider specialists as a crucial human resource for the utilisation of imaging technologies. However, since radiologists specialise in diagnose and treat diseases using medical imaging technologies, they are able to use such technologies more efficiently than non-specialists [9]. We explicitly included this aspect in our analysis. Moreover, we adopted an integrated approach to measure the adoption of imaging technologies. This is important because patients and physicians would evaluate the technological level of certain hospitals comprehensively, that is, as a mixture of imaging equipment and number of employed radiologists.

Second, we examined whether the relationship between competition and adoption of imaging technologies varies with the ownership form. Specifically, we account for the fact that private and non-private hospitals may set different goals, and thus they may react differently to competition. The effect of ownership on hospitals' performance has been a crucial issue in the literature, but results are still ambiguous [10-11]. Moreover, most studies on MAR did not look at the effect of competition by ownership type.

Third, to the best of our knowledge, this study is the first examining the relationship between competition and adoption of medical technologies using individual data on all acute hospitals in Japan.[1] As explained below, since Japan has a high number of CT and MRI scanners per capita compared to other developed countries, the determinants of their adoption deserve particular attention. In addition, there is still little evidence on the relationship between competition and technology adoption for countries other than the United States. In this respect, this study contributes to assessing whether the findings for the United States are transferable to other countries.

Japan represents an interesting context to study the relationship between competition and adoption of imaging equipment. First, imaging equipment is widely diffused in the country. In 2014, there were 107.2 CT and 51.7 MRI scanners per million population, the highest figures among the OECD counties [14]. Second, Japanese hospitals operate in competitive markets, and the degree of competition varies across regions. In 2015, the number of hospitals per million population was 66.7, which makes the country rank second among the OECD countries [14]. The 2016 Survey of Medical Institutions (in Japanese, *Iryoshisetsu Chosa*), conducted by the Ministry of Health, Labour and Welfare (MHLW), showed that the

[1] Urushi [12] and Housaka and Bessho [13] examined the diffusion of MRI scanners in Japan. The former used aggregated data at the secondary medical region level, while the latter focused on the medical institutions with MRI scanners and did not look at the ones that were likely to adopt MRI scanners.

number of hospitals per million population varied over a wide range, from 37 in the Kanagawa prefecture to 180 in the Kochi prefecture [15]. Third, hospitals are not required to submit the certification of needs and to obtain permission from the government before adopting CT and MRI. Therefore, each hospital can have own decision to adopt these technologies based on market factors such as regional competition intensity. In other countries, adoptions of imaging technologies are regulated. In the US, some states have Certificate of Need (CON) laws. These laws require health care providers to get the permission of a state board before opening a new facility or substantially expanding an existing facility and purchasing MRI is included in control subjects in some states.

The remainder of the paper is organised as follows. Section 2 describes the dataset, while Section 3 the methodology employed. Section 4 illustrates the results, which are then discussed in Section 5.

2. Data

This study was based on a comprehensive database from the Survey of Medical Institutions. The survey is conducted by MHLW on all medical institutions in Japan, and includes information such as address, ownership, number of beds, and medical equipment. Specifically, the survey asks medical institutions whether they have multi- and single-detector CT scanners, , as well as MRI scanners of more or less than 1.5 tesla (hereinafter called ‘high-performance CT’, ‘low-performance CT’, ‘high-performance MRI’, and ‘low-performance MRI’, respectively). Besides, the survey also asks the number of employed physicians for each specialty. Overall, for each medical institution the survey provides information about the performance levels of CT and MRI scanners and the number of radiologists. Using the 2011 hospital-level data, we measured the adoption of imaging technologies, the degree of competition, as well as other characteristics. Note that the 2011 wave excluded the hospitals in the Fukushima prefecture and in some parts of the Miyagi prefecture due to the Great East Japan Earthquake. As a consequence, we also excluded the hospitals whose competitors were located in these areas.

Moreover, we excluded the hospitals without acute beds (in Japanese, *Ippan Byosho*), because we assumed that hospitals for acute patients and those for non-acute patients operate in different markets, and thus do not compete with each other. In addition, being competition the focus of our analysis, we excluded the hospitals which did not have any competitor within the defined geographical area.

3. Methods

3.1 Measuring the Adoption of High-level Imaging Technologies

In order to examine the effect of competition, we run an analysis at the hospital level by focusing on high- and low-performance CT and MRI scanners, as well as on the number of radiologists. Specifically, we considered the adoption of advanced imaging technologies in both aggregate and single-technology terms.

The concept of overall imaging technologies' adoption at the hospital level was based on Spetz and Maiuro [16] and the Saidix index. This index is defined as a weighted sum of the technologies available in a hospital. The weight depends on how rare each technology is. To measure the overall advancement in imaging technologies' adoption, in this study we calculated the weighted sum of high-performance CT, high-performance MRI, and radiologists. The weight was calculated as follows:

$$a_k = 1 - \left(\frac{1}{N}\right)\sum_{i=1}^{N} \tau_{i,k}.$$

Here, N is the total number of hospitals in Japan, while $k = 1, 2, 3$ indicates high-performance CT, high-performance MRI, and radiologists, respectively. $\tau_{i,k}$ takes the value 1 if hospital i has k and 0 otherwise.

Using the weight a_k, the overall adoption of advanced imaging technologies S for hospital i was computed as follows:

$$S_i = \sum_{k=1}^{3} a_k \tau_{i,k}.$$

The index increases as the imaging technologies adopted are rarer.

As explained above, we focused on the availability of imaging technologies as of 2011, implying that we did not directly look at the actual hospital's decision to adopt such technologies. However, because the hospital competition in Japan has not drastically changed,[2] and because the medical equipment we analysed is not a recent invention, we believe that we are able to portray the long-term hospitals' decision to adopt imaging technologies.

3.2 Measuring the Level of Competition

In the related literature, two measures for hospitals' competition have been commonly used: the number of hospitals within a certain area and a Herfindahl-Hirschman Index (HHI) based on the geographical market. While the number of neighbouring hospitals does not account for their size, the HHI can reflect the competitors' size. Therefore, we adopted the reciprocal of the HHI (*RHHI*) in our base analysis. The *RHHI* value increases as hospitals face more intensive competition.[3] Moreover, under the assumption that the market is composed of equal-size hospitals, the *RHHI* is equivalent to the number of competitors.

To calculate an HHI, it is necessary to define a hospital's market area as well as its competitors. We assumed that a hospital had a 10 km market area, with all the hospitals for acute patients within this area being competitors.[4] Using the number of outpatients in September 2011 from the Survey of Medical Institutions, the *RHHI* was calculated as follows:

$$RHHI_i = 1 \Big/ \sum_{j=1}^{J} \left(\frac{P_{j,i}}{\sum_{j=1}^{J} P_{j,i}} \right)^2 .$$

In this research, we focus on diagnostic technologies that are widely open to outpatients. Thus, each hospital competes with other hospitals through diagnostic imaging technologies to attract outpatients as potential inpatients. $P_{j,i}$ is the number of outpatients visiting hospital j $(j = 1, \dots, J)$, which is located within the

[2] Since 1985, the entry of hospitals in the market has been strictly regulated at the prefectural level.

[3] The HHI ranges from zero to one; the more competitive the market, the closer to zero the HHI. The *RHHI* takes values higher than or equal to one; the more competitive the market, the higher the value of the *RHHI*.

[4] We also tried other market definitions to check the robustness of our results.

10 km radius of hospital i. $\frac{P_{j,i}}{\sum_{j=1}^{J} P_{j,i}}$ defines the market share of hospital j in the market of hospital i.

3.3 Estimation Strategy

When examining the relationship between competition and adoption of medical technologies, we potentially face an endogeneity problem, which might bias the results. This is because patients reasonably prefer hospitals with advanced medical equipment and skilled specialists. In this case, the number of patients, that is, the key component of the HHI, is associated with the level of technology. Furthermore, once new hospitals may avoid entering markets where the incumbent hospitals are characterised by advanced medical equipment and specialists, the degree of competition itself is affected by the level of technology. In these cases, the estimated results would be biased.

In order to tackle the potential endogeneity in hospitals' competition, we employed an instrumental variable approach [17]. Valid instrumental variables will only affect the adoption of imaging technologies through their effects on hospital competition, with which they will be highly correlated. In this study, we considered two instrumental variables: the share of three reformist parties (Komeito, Japanese Communist Party, and Social Democratic Party) in the prefectural assembly seats and the capacity of long-term care institutions per capita in each municipality. The first variable is assumed to positively affect the regional medical supply at the prefectural level, because these parties aim at beefing up social securities. The presence of these three parties, which tended to be non-ruling parties in the national assembly in 2011, may hinder ruling parties' unpopular policies such as the selection and concentration of public hospitals. However, this variable would not have a direct influence on (especially private) hospital's decisions to adopt medical technologies. The second instrumental variable is also assumed to be related to the level of regional hospital competition as the relationship between medical and long-term care seems to be great. However, it would not directly determine the adoption of medical technologies by hospitals. Therefore, these instruments are suitable for our analysis.

We estimated the following two-stage least squares (2SLS) model. In the following specification, we assumed that the adoption of imaging technologies is a function of competition as well as of hospitals and market areas' characteristics.

$$Y_i = \alpha + \beta_1 RHHI_i + \gamma' X_i + \varepsilon_i, \quad (1)$$

$$RHHI_i = \theta + \pi_1 E_i + \pi_2 L_i + \rho' X_i + \eta_i. \quad (2)$$

In Eq. (1), Y_i is the overall adoption of advanced imaging technologies as well as five binary variables reflecting the adoption of each technology: that is, whether hospital i had a high-performance CT, a low-performance one, a high-performance MRI, a low-performance one, and a radiologist. X_i contains the characteristics of hospital i and those of the related market area. More in detail, we controlled for various characteristics of the market areas such as population density and proportion of the elderly, as the degree of competition could be correlated with these regional characteristics. In Eq. (2), E_i is the share of the parties in the assembly seats in the prefecture of hospital i, while L_i is the capacity of long-term care institutions per capita in the municipality of hospital i. ε_i and η_i are the error terms in Eq. (1) and (2), respectively. The latter equation corresponds to the first stage of the 2SLS model and was used to predict $RHHI_i$. Note that Eq. (1) was also estimated by ordinary least squares (OLS).

In order to determine whether the relationship between competition and the diffusion of imaging technologies varied with hospitals' characteristics, we also run the same analysis on two subsamples based on the ownership: private and non-private hospitals.[5]

4. Results

In this study, we considered a sample of 5687 hospitals for acute patients in Japan. Table 1 presents the related descriptive statistics and shows that 76% of the hospitals had already preferred high-level CT scanners to low-level ones. On the contrary, MRI scanners and radiologists were not so widely diffused. Figure 1 shows the prefectural distribution of Saidin index. Western prefectures tend to have higher index than Eastern prefectures. Saidin index has the same distributional feature as hospital competition in

[5] In this study, private hospitals were defined as the hospitals which were managed by medical corporations, private schools, social welfare corporations, companies, and individual persons; otherwise, non-private hospitals.

prefectural level.

Table 2 reports the main results of our analysis. The results from the OLS estimation in column (1) indicate that competition was significantly and negatively correlated with the overall adoption of advanced imaging technologies (-0.0007, $P < 0.05$). The result of the first-stage estimation of the 2SLS model in column (2) shows that the instruments were strongly correlated with the degree of competition, while the second-stage estimation in column (3) highlights a positive and significant relationship between competition and overall level of adoption (0.0025, $P < 0.05$). Compared to the OLS estimate, the 2SLS estimate of the effect of competition is much larger. This result confirms our concerns about endogeneity, as the OLS result can be biased downward in our case. Column (3) also presents the results of the endogeneity and over-identification tests. Specifically, the result of the Hausman test supports our hypothesis of endogenous competition. Note that, when a Sargan test rejects the null hypothesis, at least one instrument is not exogenous. As this is not the case for our sample, we judged the 2SLS results more reliable than the OLS ones.

Table 3 shows the results related to the imaging technologies taken individually. As shown in column (1) and (2), competition was positively related to the adoption of high-level CT scanners, but not statistically significant at 5% level, while it was negatively and significantly related to that of low-level CT scanners. In column (3) and (4), we present the results for MRI. The estimated coefficients for MRI were lower than those of the other technologies. In this respect, we found no evidence that competition could be associated with the adoption of MRI scanners. Furthermore, as shown in column (5), competition and the number of radiologists emerged to be significantly and positively related.

In Table 4, we show the results of the 2SLS estimation on two subsamples (private and non-private hospitals). The estimated coefficient for private hospitals was larger (and statistically significant) than that (non-significant) of non-private ones.

Finally, Table 5 shows the robustness checks. Since there is no broad consensus on the definition of geographical areas for hospitals' competition, we tried various types of competition measures. First, after assuming that hospitals had 10 km market areas in the base analysis, we tried market areas of 5 and 15 km, as shown in column (1), (2), (3), and (4). In column (5) and (6), we report the results with the *RHHI* calculated using the number of inpatients on 30 September 2011 instead of that of outpatients in the same month. In column (7) and (8), instead, we considered the number of hospitals within a 10 km radius rather than the HHI as a measure of competition. As can be seen from the table, the relationship between competition and the overall adoption of advanced imaging technologies was not sensitive to the definition of the competition measure.

5. Discussion and Conclusion

This study examined the relationship between hospitals' competition and adoption of imaging technologies in Japan. Differently from standard evaluations, this was done by measuring the adoption of advanced imaging technologies at both aggregate and single-technology levels. Using an instrumental variable approach to address potential endogeneity problems, we found that competition was significantly and positively related to the overall adoption of advanced imaging technologies. Once we focused on individual imaging technologies, this result kept true for high-performance CT scanners and radiologists, but not for high-performance MRI scanners.

A major strength of our study consisted of the access to a comprehensive government survey targeting all hospitals in Japan, which fostered an accurate understanding the drivers of the adoption of imaging technologies. Based on this data, we highlighted a relationship not reported by previous studies. More in detail, the relationship between competition and the adoption of CT scanners emerged to be dependent on their performance. This suggested that competition does not merely promote the adoption of devices irrespectively of their performance, but rather the update of particular technologies. Moreover, competition seemed to encourage the hiring of radiologists.

The patient-driven MAR might explain why hospitals' competition in Japan has been so related to the adoption of imaging technologies. More specifically, in the country, under the universal health care system, patients are allowed to freely select the medical institutions to visit: even without referrals, they can directly visit hospitals, and outpatient services in hospital are very popular. Moreover, the prices of medical services are regulated by the government. Such institutional settings may incentivise the patient-driven MAR. Nonetheless, hospitals may be willing to participate in the MAR in order to employ physicians, not to attract patients. Physicians may choose hospitals offering an attractive working environment: for example, in hospitals with high imaging technologies, patients could be treated after efficient and correct diagnostic procedures. This is consistent with our results, as it would be hard for patients to clearly disentangle the performance of medical equipment and the specialties of physicians. Overall, the need for attracting either patients or physicians might explain MAR participation.

Among the OECD countries, Japan has the highest number of CT and MRI scanners per capita. Our results suggest that intense hospitals' competition may contribute to the widespread diffusion of imaging equipment, especially CT scanners. However, this does not necessarily improve people's health. Evidence shows that the exposure to CT scan might increase the risk of cancer [18]. Therefore, the diffusion of CT scanners may not only raise healthcare costs, but also, if overused, have a negative impact on health. If this is the case, regulations of the adoption of imaging technology may be needed. In the USA, for example, some states require Certificate of Need board approval for purchasing MRI scanners. Even by assuming a positive effect of CT scanners on people's health, our findings still highlight that, despite the universal health care system, the access to beneficial imaging services is not uniform, which raises concerns for equity. In either case, our results do not support the idea that raising competition leads to the decrease in medical expenditures.

Our results also suggest that the private hospitals have been more prone to competition than non-private ones. While previous research suggests the importance of the health insurance market structure for the emergence of the MAR [3-4], this study points out that such an effect depends, at least partially, on the ownership type. This implies that competition policy in the health care market would have a strong effect in Japan, because of the major role played by private hospitals. Although a policy permitting hospitals owned by for-profit companies to enter the health care markets has been considered [19], our findings show that this type of competition policy may lead to the growth of medical expenditures through the adoption of advanced technologies.

Some limitations of this study should be acknowledged. First, this study is a cross-sectional analysis, and thus does not include a temporal perspective. Second, although we adopted the instrumental variable approach and controlled for various hospital and market characteristics, the presence of unobserved factors may have biased our results. Third, due to the lack of data, we could not show the actual utilization of CT scanners, MRI scanners, and radiologists, as well as their impacts on health. Forth, we only used the data of hospitals, not clinics. Some hospitals outsource imaging technology to surrounding clinics in Japan. If outsourcing decisions are related to hospital competition, this analysis can underestimate the effects of competition on technology adoption.

In summary, we performed a cross-sectional analysis using government survey data on all acute hospitals in Japan. Based on an instrumental variable approach to address potential endogeneity problems, we found that competition was significantly and positively associated with the overall adoption of advanced imaging technologies. Competition promoted the adoption of high-performance CT scanners and the hiring of radiologists, but significantly reduced that of low-performance CT scanners. Besides, we found that competition was significantly related to technology adoption for private hospitals, while the result did not hold for non-private ones.

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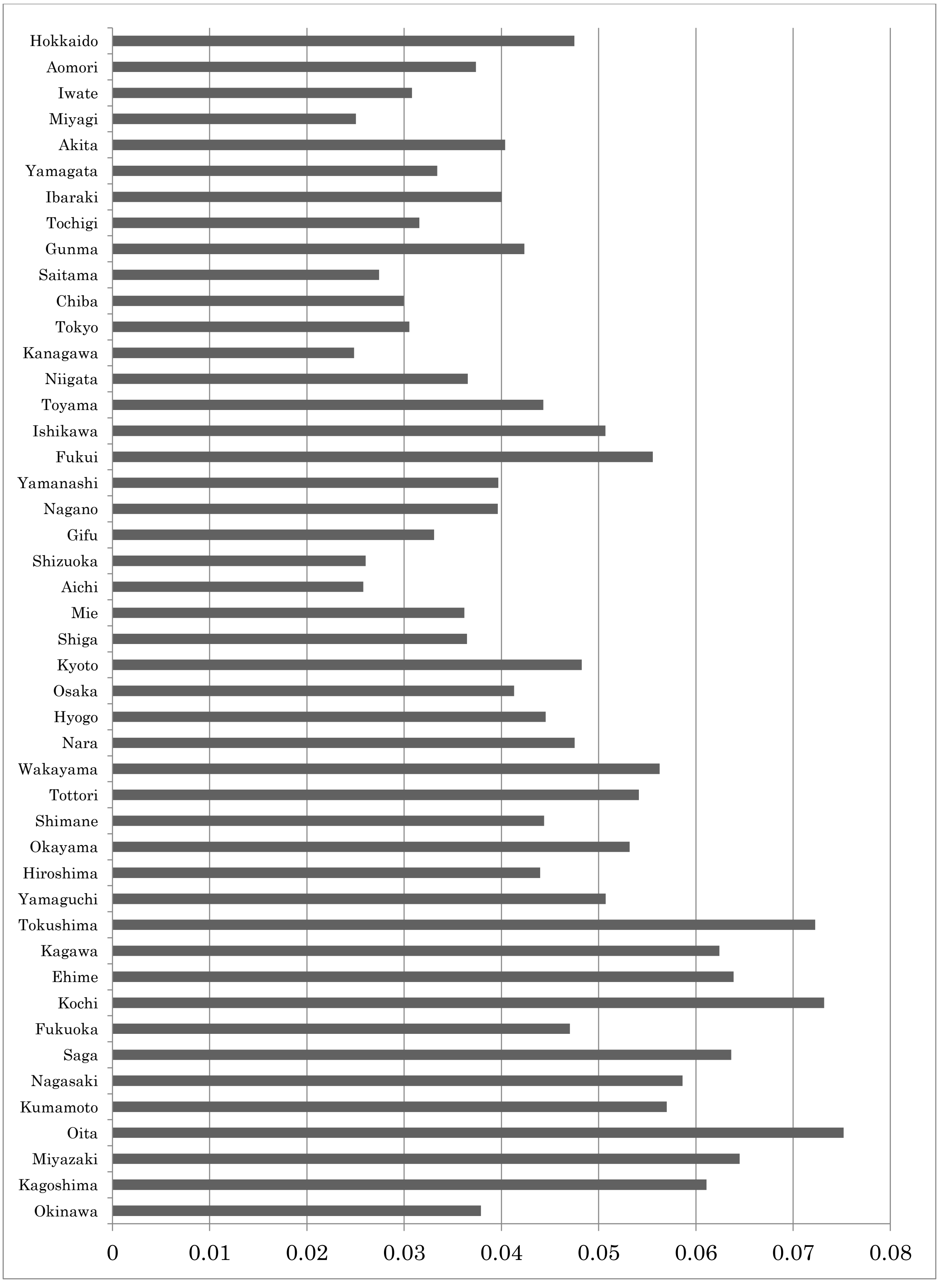
Figure 1 Prefectural distribution of Saidin index



Tables

Table 1. Descriptive statistics.

Variable	Description	Mean	S. D.	Minimum	Maximum	Source
High-performance CT	= 1 if the hospital has one or more multi-detector CT scanners; 0 otherwise	0.760	0.427	0	1	a
Low-performance CT	= 1 if the hospital has one or more single-detector CT scanners; 0 otherwise	0.176	0.381	0	1	a
High-performance MRI	= 1 if the hospital has one or more MRI scanners (not less than 1.5 tesla); 0 otherwise	0.388	0.487	0	1	a
Low-performance MRI	= 1 if the hospital has one or more MRI scanners (less than 1.5 tesla); 0 otherwise	0.196	0.397	0	1	a
Radiologist	= 1 if the hospital has one or more radiologists (based on a full-time equivalent measure); 0 otherwise	0.368	0.482	0	1	a
Overall adoption of advanced imaging technologies	The weighted sum of indicators showing whether the hospital has high-performance CT, high-performance MRI, and radiologists	0.863	0.706	0	1.872	a
RHHI	The reciprocal of the Herfindahl-Hirschman Index based on the 10 km market area	44.613	46.512	1.008	170.617	a

Teaching hospital	= 1 if the hospital is a teaching hospital; 0 otherwise	0.028	0.165	0	1	a
No. of beds						a
(70, 130]	= 1 if the number of beds in the hospital is in the interval (70, 130]; 0 otherwise.	0.247	0.431	0	1	
(130, 240]	= 1 if the number of beds in the hospital is in the interval (130, 240]; 0 otherwise.	0.248	0.432	0	1	
> 240	= 1 if the number of beds in the hospital is more than 240; 0 otherwise.	0.250	0.433	0	1	
No. of physicians per bed						a
(0.7, 1]	= 1 if the number of physicians per bed in the hospital is in the interval (0.7, 1]; 0 otherwise	0.259	0.438	0	1	
(1, 1.47]	= 1 if the number of physicians per bed in the hospital is in the interval (1, 1.47]; 0 otherwise	0.243	0.429	0	1	
> 1.47	= 1 if the number of physicians per bed in the hospital is more than 1.47; 0 otherwise	0.251	0.434	0	1	
Proportion of beds for acute patients						a
(0.25, 0.5]	= 1 if the proportion of beds for acute patients to all types of beds is in	0.155	0.362	0	1	

	(0.25, 0.5]					
(0.5, 0.75]	= 1 if the proportion of beds for acute patients to all types of beds is in (0.5, 0.75]	0.162	0.368	0	1	
> 0.75	= 1 if the proportion of beds for acute patients to all types of beds is more than 0.75	0.630	0.483	0	1	
Reginal income	The income-based levy of municipal tax per taxpayer in the municipality of the hospital (million JPY per taxpayer)	3.098	0.623	2.150	9.435	b
No. of physicians per person	The number of physicians working in hospitals per 1000 persons in the municipality of the hospital	1.667	1.618	0.050	19.060	c
No. of advanced treatment hospitals	The number of hospitals designated as advanced treatment ones by the Ministry of Health, Labour and Welfare in the 10 km market area of the hospital	0.973	2.015	0	13	a
No. of hospitals supporting regional medical care	The number of hospitals designated as regional medical care support hospitals by prefectural governors in the 10 km market area of the hospital	2.418	2.659	0	13	a
Proportion of elderly	The share of people aged 65 years and over against the total population in the 10 km market area of the hospital	0.232	0.044	0.151	0.547	d
Population density	The population density of the 10 km market area of the hospital	3344.277	3934.610	5.854	16529.610	d

Major city	= 1 if the hospital is located in the Tokyo metropolitan area or prefectural capitals; 0 otherwise	0.360	0.480	0	1	
Proportion of people with subjective symptoms	The number of persons with some subjective symptoms per 1000 people in the prefecture of the hospital	322.584	15.902	274.9	353.700	e
Regional financial power	The financial capability index of the municipality where the hospital is located	0.693	0.235	0.090	1.580	f
Parties' share in the prefectural assembly seats	The share of Komeito, Japanese Communist Party, and Social Democratic Party in the assembly seats of the prefecture where the hospital is located	0.139	0.065	0.039	0.271	g
Capacity of long-term care institutions	The capacity of long-term care institutions per capita in the municipality of the hospital	0.004	0.003	0	0.079	h

Note: source "a" refers to our main data, the 2011 Survey of Medical Institutions. The other sources are indicated as follows:

b: Ministry of Internal Affairs and Communications (2011); c: Japan Medical Association Research Institute (2013); d: Ministry of Internal Affairs and Communications (2012a); e: MHLW (2011); f: Ministry of Internal Affairs and Communications (2012b); g: Ministry of Internal Affairs and Communications (2012c); h: MHLW (2012).

Table 2.

Relationship between competition and overall adoption of advanced imaging technologies

	(1) OLS	(2) 2SLS first stage	(3) 2SLS second stage
RHHI	-0.0007** [0.0003]		0.0025** [0.0011]
Capacity of long-term care institutions		998.3638*** [126.9054]	
Parties' share in the prefectural assembly seats		100.8514*** [5.0488]	
Teaching hospital	0.0850** [0.0396]	5.6507*** [1.6805]	0.0691** [0.0297]
No. of beds			
(70, 130]	0.4141*** [0.0180]	0.3204 [0.7655]	0.4134*** [0.0184]
(130, 240]	0.7910*** [0.0179]	1.3480* [0.7617]	0.7878*** [0.0197]
> 240	1.2149*** [0.0179]	-0.2212 [0.7607]	1.2166*** [0.0170]
No. of physicians per person			
(0.7, 1]	0.2441*** [0.0184]	1.2087 [0.7818]	0.2397*** [0.0195]
(1, 1.47]	0.4242*** [0.0199]	0.7136 [0.8445]	0.4215*** [0.0212]
> 1.47	0.5990*** [0.0220]	2.0488** [0.9320]	0.5918*** [0.0237]
Proportion of beds for acute patients			
(0.25, 0.5]	0.2288*** [0.0315]	-2.1034 [1.3389]	0.2401*** [0.0342]
(0.5, 0.75]	0.3027*** [0.0322]	-1.7302 [1.3672]	0.3121*** [0.0346]
> 0.75	0.3794*** [0.0309]	-2.7001** [1.3135]	0.3915*** [0.0337]
Reginal income	-0.0871 [0.0553]	36.9405*** [2.2978]	-0.2178*** [0.0706]
Reginal income^2	0.0105** [0.0050]	-2.6238*** [0.2092]	0.0194*** [0.0060]
No. of physicians per	-0.0031 [0.0097]	-8.1335*** [0.4012]	0.0233* [0.0126]

person			
No. of physicians per person^2	0.0003 [0.0007]	0.3725*** [0.0284]	-0.0010 [0.0007]
No. of advanced treatment hospitals	-0.0020 [0.0054]	5.2669*** [0.2190]	-0.0197** [0.0078]
No. of hospital supporting regional medical care	-0.0019 [0.0037]	3.3716*** [0.1514]	-0.0145*** [0.0054]
log (Proportion of elderly)	0.0471 [0.0625]	49.8255*** [2.6011]	-0.1315 [0.0862]
log(Population density)	0.0032 [0.0118]	20.8828*** [0.4368]	-0.0687*** [0.0260]
Major city	-0.0260 [0.0174]	-14.1751*** [0.7178]	0.0285 [0.0248]
Proportion of people with subjective symptoms	0.0019*** [0.0004]	-0.0408** [0.0180]	0.0017*** [0.0004]
Regional financial power	-0.0404 [0.0464]	-16.7046*** [2.0360]	0.0596 [0.0573]
Intercept	-0.7061*** [0.1732]	-111.2427*** [7.4507]	-0.3076 [0.2194]
R^2	0.5835	0.8271	0.5749
Weak instruments		189.7620***	
Wu-Hausman test			9.4825***
Sargan test			0.1356

Note: N = 5687. Heteroskedasticity-robust standard errors are reported in brackets. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 3.

Relationship between competition and the adoption of individual imaging technologies

	(1) High-performance CT	(2) Low-performance CT	(3) High-performance MRI	(4) Low-performance MRI	(5) Radiologists
RHHI	0.0015*	-0.0021**	-0.0006	-0.0004	0.0032***
	[0.0009]	[0.0009]	[0.0008]	[0.0009]	[0.0009]
R^2	0.2117	0.0296	0.4499	0.0306	0.3945
Wu-Hausman test	3.2959*	5.5968**	0.0334	0.3294	15.5939***
Sargan test	0.1487	0.1231	0.1638	1.1228	1.4662

Note: N = 5687. This table presents the results of the 2SLS estimation. Only the coefficients of the main explanatory variable are reported. Heteroskedasticity-robust standard errors are reported in brackets. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 4.

Competition and overall adoption of advanced imaging technologies **for private and non-private hospitals**

	(1)	(2)	(3)	(4)
	Private hospitals		Non-private hospitals	
	First stage	Second stage	First stage	Second stage
RHHI		0.0034** [0.0014]		-0.0003 [0.0023]
Capacity of long-term care institutions	1687.1521*** [212.1128]		209.0169 [141.2574]	
Parties' share in the prefectural assembly seats	101.8133*** [6.3533]		82.5034*** [7.5613]	
R^2	0.8307	0.4365	0.8345	0.6364
Weak instruments	128.6636***		57.5576***	
Wu-Hausman test		8.4838***		0.0701
Sargan test		2.6553		1.5979
N	3879	3879	1808	1808

Note: This table presents the results of the 2SLS estimation. Only the coefficients of the main explanatory variable are reported. Heteroskedasticity-robust standard errors are reported in brackets. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 5. Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	5 km		15 km		Inpatient number based HHI		Number of rival hospitals	
	First stage	Second stage	First stage	Second stage	First stage	Second stage	First stage	Second stage
RHHI		0.0044*		0.0020***		0.0018**		0.0010**
		[0.0023]		[0.0008]		[0.0008]		[0.0004]
Capacity of long-term care institutions	382.3749***		1833.8398***		1231.9734***		2275.7250***	
	[73.6543]		[182.8141]		[166.1754]		[352.1909]	
Parties' share in the prefectural assembly seats	50.2388***		137.9882***		144.3441***		258.3202***	
	[2.2351]		[7.6046]		[6.6111]		[14.0116]	
R^2	0.7571	0.5806	0.8678	0.5753	0.8211	0.5753	0.8299	0.5731
Weak instruments	230.3987***		143.2607***		216.4414***		159.2374***	
Wu-Hausman test		7.9475***		9.9956***		10.5305***		9.5671***

Sargan test		1.0905		1.2058		0.0683		0.0798
N	5513	5513	5676	5676	5687	5687	5687	5687

Note: We excluded the hospitals without beds for acute patients, the hospitals located in the Fukushima Prefecture as well as in some parts of the Miyagi Prefecture, the hospitals whose rivals were located in these areas, and hospitals without competitors. This is the reason why the number of hospitals in the sample varied according to the definition of the market area. The table presents the results of the 2SLS estimation. Only the coefficients of the main explanatory variable are reported. Heteroskedasticity-robust standard errors are reported in brackets. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.