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RIETI Discussion Paper Series 25-E-101

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https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 25-E-101
October 2025

Actual Hospital Bed Utilization by Institutional Ownership during the COVID-19 Omicron Variant Epidemic in Japan[1]

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Abstract

During the summer of 2021 in Japan, COVID-19 patients faced admission difficulties despite beds being available due to capacity mismatches. This study analyzes hospital admission patterns during the Omicron variant expansion (December 2021–March 2022), focusing on institutional ownership of acute care hospitals. Publicly owned and non-governmental hospitals may differ in their relationships with prefectural governments responsible for securing beds through vertical administrative structures. The analysis examines metropolitan versus non-metropolitan areas and hospitals with or without other acute care facilities within 10 km, comparing COVID-19 inpatients per 100 beds and reserved bed occupancy rates between ownership types. Results reveal that bed allocation ratios for COVID-19 patients vary between ownership types. Significant differences in inpatients per 100 beds appear in regions with nearby acute care hospitals and in non-metropolitan areas. Reserved bed occupancy rate differences between ownership types emerge in regions with proximate hospitals but not in single-hospital regions. Metropolitan areas frequently show no significant occupancy differences, indicating admissions matched reserved capacity. Findings demonstrate the necessity of strategic bed planning, particularly highlighting that non-governmental hospitals without nearby facilities face difficulties securing beds through administrative relationships. Enhanced monitoring during outbreaks is essential for such isolated hospitals.

Keywords: COVID-19, Bed utilization, Institutional ownership
JEL classification: C14, I18, I19

[1] This study is conducted as a part of the Project "On Productivity Growth through Comprehensive Capital Accumulation" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The authors are grateful for helpful comments and suggestions by Eiichi Tomiura (RIETI), Tsutomu Miyagawa (Gakushuin Univ.), Tatsufumi Aoyama (RIETI), Hiroshi Ikari (RIETI), and other seminar participants at RIETI. The authors also gratefully acknowledge the Japan Society for the Promotion of Science (JSPS KAKENHI: Grant Numbers JP25K05052 and JP21K01507) for financial support.

1. Introduction

COVID-19, first identified in Wuhan, China, spread globally. In New York City, which recorded the highest mortality rates in 2020, the death toll from COVID-19 exceeded 10,000 on April 13, 2020, just one month after the outbreak was announced. To accommodate infected patients and reduce mortality, health care facilities suspended treatment for non-COVID-19 patients, converted wards and lobbies into patient rooms, and mobilized field hospitals and hospital ships. However, this phenomenon was not specific to New York City, as numerous countries prioritized securing hospital beds. In India, for instance, hospital beds were allocated for COVID-19 patients, and their numbers were flexibly adjusted according to infection rates (Archana Mishra, 2020). However, when hospitals admitted COVID-19 inpatients, they had to allocate human and material resources to these patients while simultaneously restricting the (partial) admission of non-COVID-19 patients, resulting in decreased medical revenue. Hospitals may hesitate to accept patients when confronted with COVID-19-specific challenges, namely, the allocation of limited physical and human resources and the opportunity costs associated with accepting COVID-19 patients. Thus, during outbreaks of infectious diseases, the inability to secure hospital beds for inpatients becomes a significant societal concern.

Japan was no exception, despite its relatively low COVID-19 mortality rate compared with many other countries. In June 2020, the Japanese government initiated a comprehensive support package for preparing reception beds, beginning with subsidies for securing hospital beds for COVID-19 inpatients.[1] As described in Section 3, these subsidies were allocated to beds suspended for

[1] Details are provided in Section 3. Besides direct subsidies for securing beds, the support included the following: (i) increased medical fees for COVID-19 patients; (ii) equipment procurement support; (iii) subsidies for securing physicians and nurses; (iv) subsidies for medical institutions with infection clusters; and (v) subsidies for the development of patient transportation systems. For more information on developments regarding bed securing, see Masuhara and Hosoya (2022, 2023b).

accommodating COVID-19 inpatients and unused beds resulting from ward closures (while beds with patients under treatment incurred higher-than-normal medical fees). However, shortly before the Tokyo Olympics in summer 2021, COVID-19 positive cases surged in urban areas, and the media raised concerns about two issues—namely "medical refugees," who could not be hospitalized for COVID-19 treatment, and the problem of "ghost beds," where hospitals received subsidies without accepting inpatients. Edamatsu et al. (2021) identified several issues, including that subsidies were excessively allocated, some hospitals received disproportionate subsidies, and subsidized beds were insufficiently utilized, which suggested potential misuse. In December 2021, in response to the problems of medical refugees and ghost beds, the government began publishing the status of secured and utilized beds by medical institutions. Concurrently, it reduced subsidy amounts to eliminate any incentives for misuse.

Given the significant tax expenditure and critical deficiencies observed in hospital bed utilization—a matter of considerable importance to public welfare—the Japanese Board of Audit initiated a comprehensive investigation. This investigation was documented in Board of Audit in Japan (2023). Specifically, the audit examined 496 national hospitals with COVID-19 beds in 2020 and 2021 (accounting for 14.2%) and verified subsidy applications and reports through on-site accounting inspections. The findings revealed that certain hospitals refused patient admissions despite receiving subsidies, citing nursing staff shortages. While subsidies totaling 3.3848 trillion yen were disbursed to 3,483 medical institutions during the 2020–2021 fiscal years, the audit highlighted that 43% of hospitals maintained average bed utilization rates below 50% in January 2021, which is when COVID-19 hospitalizations peaked.

A critical issue that the Board of Audit in Japan (2023) report highlights concerns the underlying reasons for patient admission refusals.[2] An explanation

[2]As is widely recognized, COVID-19's high transmissibility necessitates entire hospital wards being dedicated to treating infections. Advanced medical institutions, such as university-affiliated teaching hospitals, which may find such arrangements practically chal-

frequently cited in the report is the mismatch between patient attributes and hospital capabilities. While we find it difficult to readily accept this mismatch as a legitimate justification, given that hospitals presumably understand their operational capacity before they apply for subsidies, it is essential to verify the authenticity of these claims.

Though the Board of Audit in Japan (2023) report contains rational elements, the unavoidable circumstances warrant a discussion of whether they necessarily affect all hospitals universally. Indeed, patients with moderate to severe COVID-19 require acute care, which limits the number of facilities in Japan capable of treating them. When Regional Medical Care Support Hospitals (RMCSHs)—institutions formalized to provide regional acute care with few alternative facilities—reject admissions, local residents face severe consequences. Such hospitals should, regardless of their specific attributes, accommodate COVID-19 patients in proportion to regional case numbers. An investigation of this expectation constitutes the key objective of the present study.

Consequently, we focus exclusively on RMCSHs—the core frontline units for COVID-19 response, which are responsible for regional acute medical care—to examine whether disparities in COVID-19 inpatient admissions occurred based on hospital attributes. By limiting our analysis to acute care hospitals, we enhance the sample's homogeneity and facilitate the achievement of our stated objective. We must also account for patient-side factors, particularly regarding hospital selection options. However, Japan's strained COVID-19 treatment system left patients with conditions beyond mild symptoms with minimal choice. Especially in regional areas, prefectural authorities had no alternative but to rely on the one or two available RMCSHs, which suggests a near-unique response pattern. Additionally, our study period coincides with a nationwide surge in infections, which suggests similar circumstances across medical institutions. Therefore, focusing solely on supply-side factors enables us to achieve our research objective.

lenging, might understandably refuse admissions under certain circumstances.

This study focuses on the key attribute of hospital ownership structure. This analytical choice stems from our consideration of potential differences in responses when prefectural governments request hospitalization for COVID-19 patients, particularly whether the hospital maintains a vertical relationship with local governmental authorities. While differences in patient acceptance rates across ownership structures are not self-evident a priori, national and municipal hospitals might receive prioritized requests from prefectural governments, potentially resulting in differential admission patterns across institutions. Moreover, during the hospitalization surges that accompany the spread of viral variants, admission requests may have been made regardless of ownership structure, possibly diminishing any utilization disparities. We investigate the underlying factors of such mismatches.

Under the subsidy program for securing hospital beds, RMCSHs—primary COVID-19 response institutions that voluntarily participated in the program—should theoretically operate secured beds at near-full capacity, assuming benevolent intentions. Moreover, patient acceptance behaviors should exhibit similar distributions regardless of the ownership structure. If distributions differ significantly despite bed shortages, then one could reasonably conclude that structural problems exist, such as prefectural requests being disproportionately directed at specific hospitals or institution-specific circumstances affecting admissions. While the sample composition by ownership category was disclosed in Board of Audit in Japan (2023), an analysis based on these differences was not conducted. Our hypotheses discussed in Section 5 posit that approaches to infectious disease management may vary by hospital attributes, that institutions may fulfill different expected roles, and that these factors potentially influence actual bed utilization patterns. Furthermore, if disparities exist between urban areas with relatively numerous hospitals and rural regions that lack alternatives for acute care, then this would indicate inadequacies in the COVID-19 treatment system. Subsidies were disbursed under the condition that thorough preparations would be made, with patient acceptance being guaranteed except under exceptionally unusual circumstances. Despite the emergency, if RMCSHs could not adequately respond to it, then this would suggest fundamental limitations in the RMCSH framework. Additionally, if patients were frequently excluded from transportation targets by prefectural headquarters or public health centers, or conversely, if hospitals regularly refused requested patients while citing incompatibility with institutional capabilities, then this would indicate an inability to respond effectively to future pandemics. Such a scenario would necessitate the reconstruction of the treatment system, for which this study aims to provide essential analytical material. This paper's research questions and hypotheses are grounded in the historical context of Japan's health care system. These issues are elaborated in subsequent sections.

The remainder of this paper is structured as follows: Section 2 synthesizes the relevant literature. Section 3 elucidates Japan's health care delivery system, particularly the RMCSHs responsible for acute care and hospital beds, as stipulated by the Medical Care Act. Furthermore, the section explains the misalignment between countermeasures established under the Infectious Diseases Control Law and COVID-19 before explicating the mechanisms of secured beds and subsidies implemented to address this discrepancy. Next, Section 4 describes the data used in the study and illuminates the distinctive characteristics of two ownership categories—namely national/municipal hospitals and non-governmental institutions. In Section 5, we employ non-parametric testing to determine whether significant differences exist between ownership types regarding the number of COVID-19 inpatients per 100 beds and the proportion of inpatients relative to secured beds. The analytical framework incorporates two additional layers beyond ownership structure: metropolitan versus non-metropolitan areas and regions with high versus low population densities. Lastly, Section 6 presents a comprehensive summary of the study as well as its conclusions.

2. Related literature

This study investigates the actual situation regarding the admission of COVID-19 patients in Japan from various perspectives, targeting nationwide RMCSHs with relatively similar characteristics. Its primary purpose is to examine the actual situation of patient admissions at various time points during the COVID-19 outbreak and subject the findings to statistical analysis. While this study does not intend to address the problem of ghost hospital beds directly, this issue cannot be ignored because the hospitals under consideration are implicated in the problem. Board of Audit in Japan (2023)'s detailed ex post facto survey investigated the status of the reservation and utilization of COVID-19 hospital beds.

2.1. A closely related study: Board of Audit in Japan (2023)

The aforementioned survey covered 496 medical institutions (14.2% of the total) out of 3,483 medical institutions nationwide that participated in the national project to reserve COVID-19 patient beds from FY2020 to FY2021. These institutions were required to fulfill various conditions, such as having a certain number of reserved beds and maintaining those reservations at the end of FY2021. The main findings are as follows:[3]

- In January 2021, the highest number of COVID-19 admissions occurred, yet 43% of hospitals had an average utilization rate below 50% of their number of reserved beds.

- Although the main purpose of the project was to compensate hospitals for opportunity losses, the subsidy amount sometimes exceeded losses or was insufficient to compensate for them. The background factors were thought to include problems with facility standards, patient severity, and treatment details.

[3] See Board of Audit in Japan (2023) for detailed figures.

- Regarding the reasons for inactive beds, some respondents indicated that there were few requests for admission. Many also cited a mismatch between patients and hospital characteristics.
- Similarly, regarding reasons for inactive beds, among hospitals that responded that they had refused requests for inpatient admissions, many cited inadequate medical/nursing arrangements or other indicators of insufficient preparedness.
- Although inactive beds may have sometimes been unavoidably generated, from a different perspective, hospitals would have applied for and received subsidies despite the beds not actually being available for inpatient use.

In consideration of the Audit Board's views, we wish to comment on the above. First, while there is room for debate as to whether the term "ghost beds" is appropriate, the fact remains that the number of inactive beds was not small; thus, it must be said that both the hospitals that received the subsidies and the government that provided them were partially at fault. Consequently, it cannot be said that the subsidies were efficiently utilized and that the policy effects initially intended were fully realized. Board of Audit in Japan (2023) has highlighted the need to the government to conduct verification work with a view to similar situations in the future regarding the nature of subsidies for reserved hospital beds in the event of another pandemic. Possible examples include examining the appropriateness of setting the maximum amount of the fee for reserved beds and the method of calculating the subsidy amount based on the actual situation of the medical care delivery system.

Because Board of Audit in Japan (2023) is particularly closely related to our study compared with the other studies mentioned below, it is important to briefly clarify the points of difference. In Board of Audit in Japan (2023), while the differences in hospital ownership are clarified, the analysis is not conducted with ownership as a central focus. The authors approach the reasons for the emergence of inactive beds through a questionnaire survey of subsidized hospitals as a single group. By contrast, the main objective of the present study is to examine the possibility that differences in ownership may be reflected in differences in pandemic responses. Our analysis is therefore fundamentally distinct in this respect. Moreover, it is of interest to study the analysis results by not only ownership but also the various factors related to the attributes of hospital location.

2.2. Other related literature

Takaku and Yokoyama (2022) also studies the effects of subsidies paid to hospitals during the pandemic period. Monthly panel data are constructed based on a questionnaire survey of more than 300 hospitals in Tokyo, and an empirical analysis using instrumental variable estimation is conducted to examine the impact of COVID-19 on the number of patients and medical business revenue. They highlight that, considering the impact on financial conditions, only a limited number of hospitals are capable of successfully dealing with infectious diseases. Therefore, concentrating COVID-19 patients in large hospitals and the maintenance of normal medical care in other facilities is identified as desirable pandemic response. In addition, because of the enormity of the impact of responding to COVID-19 on hospital management, the authors also suggest that subsidies should be promptly disbursed to ensure the same level of medical revenue as before. Although responding to outbreaks is no easy task, their results have some overlap with those of our study regarding how to treat patients with COVID-19.[4]

A distinctive feature of this study is that we explicitly consider differences in hospital ownership. In health economics, well-known studies have examined whether differences in ownership affect health care outcomes through, for instance, differences in hospital management structures (Lien et al., 2008; Pérotin et al., 2013; Moscelli et al., 2018). Among them, Lien et al. (2008) provide an

[4]Other studies related to subsidies include Narita and Yata (2024) in the United States and Furuhata and Araki (2024) in Japan. The latter advocates for the need to improve institutional design based on empirical studies as well as Board of Audit in Japan (2023).

interesting study set in Taiwan, where a national health insurance system has been in place since 1995. They demonstrate that patients admitted to non-profit hospitals receive higher-quality care, as assessed by mortality rates, using instrumental variable estimation that accounts for endogeneity. While the present study does not evaluate treatment outcomes, if there is some trend toward ownership in hospitals that accept more COVID-19 patients, then this may have an influence on treatment quality, which could be an important topic for future research.

Significant reductions in hospital admissions and outpatients occurred in the early stages of the pandemic. Ii and Watanabe (2022) explores the causes and indicates the underlying problems in the Japanese health care system. Notably, the drastic reduction of medical care outside of COVID-19 led to a broader collapse in healthcare services. The authors attribute this collapse to the long-standing problems with the current health care payment system and governance structure in Japan. These are precisely the same issues raised prior to the pandemic, and the experience of the pandemic can be considered to have brought them into even greater relief.

Reif and Schubert (2024) examines the impact of hospital financial support measures in Germany using intensive care unit (ICU) occupancy rates as a target indicator. However, their event study that compares pre- and post-occupancy rates uncovers no evidence of meaningful hospital behavior changes. Kraus et al. (2025) also report that in European countries, the fight against the unknown infectious disease caused major disruptions to hospital management systems and highlighted various problems. Furthermore, Barbash et al. (2024) examine data from 217 acute care hospitals in the United States and determine the importance of interhospital coordination, which has also received considerable attention in Japan. Their findings are important because the RMCSHs that we focus on are inevitably expected to play a central role in such coordination. Sen-Crowe et al. (2021) investigate the relationship between the availability of medical resources (e.g., ICU beds) and COVID-19 mortality rates in 183 countries during the early phase of the pandemic. Although they fail to produce clear results, due in part to the pandemic being in the early stage, they suggest that the reporting of information on COVID-19 indicators and related medical resources should be mandatory in light of the usefulness of such evidence for the future. In an early study of COVID-19, Berger et al. (2022) analyze ICU capacity at the national and regional levels across 16 European countries and the Lombardy region of Italy and confirm that while ICU utilization rates did not exceed 38.3%, without surge capacity, treating all COVID-19 patients needing intensive care would have been impossible.

Throughout the pandemic period in Japan, experts with clinical knowledge, including infectious disease specialists, appeared daily on TV news and other media, and their influence on the public's understanding of COVID-19 and the nature of their behaviors was considerable. Okuse (2024) and Inoue (2024), from the standpoints of a physician and a nurse, respectively, provide detailed retrospective reviews of the situation at Kawasaki Municipal Tama Hospital, which treated patients with moderate symptoms as part of the "Kanagawa Model" for dealing with COVID-19 patients in Kanagawa Prefecture. In Anan (2022), Dr. H. Anan, who led the Kanagawa Model, reviews the medical care delivery system and provides guidelines for the future, highlighting, for example, the importance of developing systems capable of accommodating surge capacity. In such a system, RMCSHs would be expected to serve as hubs for interhospital coordination.

Smooth medical coordination in a community can be inferred to be quite difficult to achieve without prior arrangements; nevertheless, several successful examples exist. Matsumoto (2021) discusses the ideal medical system based on observations during the early stages of the pandemic and highlights the "Matsumoto Model" in Matsumoto City, Nagano Prefecture, and the "Sumida Model" in Sumida Ward, Tokyo, as noteworthy success stories.[5] Incidentally, it is well known that (regional) public health centers in Japan play a central role in re-

[5]Suzuki (2021) also references the Matsumoto Model as a successful example among severe criticism of the lack of cooperation among hospitals.

sponding to infectious diseases together with medical institutions; thus, they have accumulated basic information on infectious diseases in their areas of jurisdiction, including the route of infection among infected persons. To improve future efforts, it is necessary to verify such accumulated data from various perspectives with high precision. One such attempt is provided by Hijikata et al. (2024). They use data on 11,252 COVID-19 registrants (representing all infected known infected individuals) in one administrative ward in Tokyo from February 2020 to November 2021 to clarify the characteristics of cases in the 1st through 5th waves. Considering the response to new infectious diseases based on the analysis results, the authors argue that rapid identification of the infection situation is the most critical factor for ensuring effective countermeasures against infectious diseases. Along with the rapid expansion of initial testing, they also emphasize that sufficient inpatient beds must be reserved in cases of significant disease severity.

Based on the reviewed studies, it is essential for medical and public health institutions to cooperate smoothly while exerting their respective expertise in the treatment of infectious diseases that require emergency responses. In view of the need to provide advanced care to patients with COVID-19 of moderate severity or higher while avoiding sacrificing normal care as much as possible, RMCSHs are expected to play a central role in infectious disease care. It is therefore assumed that, at least during a nationwide outbreak, regardless of hospital ownership or location (urban or rural), similar patient admission situations are likely to occur in which the utilization of hospital beds is close to maximum capacity. As noted before, the main objective of the present study is to statistically confirm such situations.

3. Japan's health care delivery system

Under Japan's Medical Care Act, a "hospital" is defined as a facility with 20 or more beds for inpatient care. This definition has remained unchanged since 1948. Medical institutions with 19 or fewer beds are classified as clinics, though most clinics are outpatient-only facilities. Just before the pandemic in 2019, Japan had 8,300 hospitals and 102,616 general clinics. Under this classification system, university-affiliated teaching hospitals with over 700 beds that conduct clinical research and education; municipal hospitals with approximately 400 beds that provide acute care as regional core facilities; and private hospitals with fewer than 100 beds that have evolved from clinics are all categorized as hospitals under the Medical Care Act. Furthermore, for-profit hospitals are prohibited in Japan, but there are no other restrictions on the entities that can establish hospitals. Theoretically, an individual physician could establish a clinic, gradually increase its bed capacity until it becomes a hospital, and potentially expand further into a 400-bed regional core hospital, or they could even establish a private university-affiliated teaching hospital. Table 1 presents the distribution of hospitals by founding entities and bed capacities. Although there is a mix of national and municipal hospitals and other types of founding entities, university-affiliated teaching hospitals are primarily national institutions. By contrast, regional core hospitals are typically national or municipal, or they are operated by public organizations like the Red Cross. Private hospitals predominantly have fewer than 200 beds, as shown in Table 1. Since for-profit hospitals are prohibited in Japan, private hospitals are classified as non-profit hospitals.[6] Although Red Cross hospitals and agricultural cooperative hospitals are categorized as public medical institutions, we classify them as "non-governmental hospitals" in this paper to clearly distinguish them from national or municipal hospitals (which we refer to here as "publicly owned hospitals").

Due to the relatively lenient definition of a hospital requiring only 20 or more beds, a diverse range of medical institutions are classified as hospitals in Japan. However, in actual practice, since the treatable conditions vary according to bed capacity, functional differentiation (role allocation) is guided through

[6]While private hospitals are prohibited from distributing dividends to external parties, they are subject to corporate tax obligations under the tax law.

Table 1: Number of hospitals by total beds and ownership type (excluding psychiatric hospitals)

	Publicly owned hospitals		Non-governmental hospitals	
	National hospitals	Municipal hospitals	Red Cross, Agricultural cooperatives, etc.	Other NGOs
20–99 beds	11	286	29	2,543
100–199 beds	54	210	75	2,000
200–399 beds	118	206	121	763
400–799 beds	114	160	93	205
800 beds or more	16	14	5	43
Total	313	876	323	5,554

Note: Private hospitals are included under "Other NGOs."

reimbursement schedules (pricing). Additionally, to confer legal status on core regional hospitals, "Advanced Treatment Hospitals" were institutionalized in 1993, followed by RMCSHs in 1997. The former primarily target university-affiliated teaching hospitals, while the latter focus on regional core hospitals. As of September 2024, there are 88 Advanced Treatment Hospitals and 707 RMCSHs. RMCSHs are defined as regional core hospitals that provide emergency medical services, perform surgeries, admit patients referred from other facilities, share medical equipment with different providers, and support primary care physicians. The approval requirements for RMCSHs are specified as follows: they must have emergency medical care capabilities; maintain a referral rate (i.e., the proportion of referred patients and emergency patients among all new patients) of at least 80% (or 65% or more with a reverse referral rate of 40% or more, or 50% or more with a reverse referral rate of 70% or more); make their buildings, facilities, and medical equipment available for use by local physicians; provide training for regional health care workers; and generally have a minimum capacity of 200 beds.

Here, we provide additional context regarding the inclusion of emergency medical care in the requirements for RMCSHs. As shown in Table 1, many Japanese hospitals are relatively small in scale; consequently, not all hospitals provide emergency medical services 24/7 (24 hours a day, 7 days a week). Instead, hospitals in a region often operate on a rotational basis to provide emergency care. In such arrangements, patients who require emergency surgery may not receive adequate treatment at smaller facilities and must be transported to hospitals with ICUs in the region. The absence of hospitals capable of handling emergency medical care in a region significantly diminishes the benefits to local residents. Therefore, Japan's Ministry of Health, Labour and Welfare has requested that prefectures establish at least one RMCSH within each Secondary Medical Area. While some Secondary Medical Areas in depopulated regions lack RMCSHs, most areas have at least one such facility. Crucially, hospitals that are capable of providing intensive treatment requiring substantial human and material resources in Japan are primarily RMCSHs and Advanced Treatment Hospitals (essentially university-affiliated medical institutions).

Next, we explain the legal categorization of hospital beds in Japan. Under Japan's Medical Care Act, only the following five types of hospital beds are defined: general beds, long-term care beds, psychiatric beds, infectious disease beds, and tuberculosis beds. Except for general beds, each category serves patients with specific conditions. Long-term care beds (numbering 308,444 as of 2019, immediately before COVID-19, as are all subsequent figures) are designated for patients who require nursing care (in Japan, some patients who would receive long-term care services in other countries are covered under health insurance). Psychiatric beds (numbering 326,666) are for patients with mental health conditions. Infectious disease beds (numbering 1,888) are designed to accommodate patients with novel infectious diseases. Tuberculosis beds (numbering 4,370) were established to address Japan's tuberculosis epidemic in the first half of the 20th century. General beds (numbering 887,847) encompass all beds that do not fall into the aforementioned four categories. Since general beds include all beds without disease-specific limitations, they cover a broad spectrum of care. This category includes ICUs for emergency patients who require sophisticated 24-hour monitoring as well as beds for routine post-operative care (unlike in the United States, Japan's average post-operative hospital stay remains approximately 12 days even in 2025) and rehabilitation beds (inpatient rehabilitation is permitted in Japan). Consequently, while the number of general beds is substantial, it is essential to note that not all are equipped for advanced patient monitoring. Although various types of patients are admitted to general beds, they are not subject to uniform usage fees; different pricing structures apply according to purpose. ICUs, which require greater human and material resources, have higher daily usage fees to offset these costs (Japan's DRG-PPS uses a per-day fixed rate that decreases with length of stay, rather than a per-admission fixed rate). By contrast, rehabilitation-specific beds have relatively lower fees due to reduced staffing requirements. Furthermore, infectious disease and tuberculosis beds are legally required to have complete isolation capabilities, mechanical ventilation systems, and disinfection equipment to prevent nosocomial infections, whereas general beds are not subject to these requirements. COVID-19 response measures involving hospitals and beds are also implemented according to separate infectious disease legislation, which we explain next.

Japan's infectious disease control is based on the Infectious Diseases Act. It involves the collection of information on infectious diseases and their classification according to their transmissibility and severity, followed by the implementation of corresponding preventive measures (e.g., administrative hospitalization orders, disinfection, and travel restrictions). When COVID-19 first emerged in 2020, it was classified as a "Class 2" infectious disease—the same category as tuberculosis, SARS, and MERS. This represented the second most stringent classification, although less severe than Ebola hemorrhagic fever or plague. This legal classification empowered the government to mandate disinfection and hospitalization. Within the Infectious Diseases Act framework, hospitals and beds designated for treatment are predetermined. For COVID-19, around February 2020, the plan was to utilize the 351 Type II Designated Medical Institutions for Infectious Diseases nationwide (medical institutions for treating patients with Class 2 infectious diseases) with their 1,758 infectious disease beds. Additionally, 184 medical institutions with tuberculosis beds and equivalent facilities were available, providing 3,052 beds. Even when specialized infectious disease beds with functionally equivalent tuberculosis beds were combined, there were only 4,810 beds, for a total of approximately 3.86 beds per 100,000 population. This figure equates to merely 0.54% of the 887,847 general hospital beds (approximately 731 beds per 100,000 population) available in 2019. Due to the broad scope of general beds, a "Hospital Bed Function Report" system was implemented in 2016, which requires the self-reporting of bed functions. According to this system, "advanced acute care beds" and "acute care beds" for acute inpatient care totaled 711,000 nationwide (approximately 571 beds per 100,000 population). Even when we limit the comparison to these beds, isolation-capable beds for infectious diseases constitute only 0.68%. Having not experienced a pandemic for an extended period, Japan had prepared only the minimum number of isolation-capable beds necessary.

On February 29, 2020, Nishiura (2020) projected that the peak incidence would reach 8,987 cases per 100,000 population per day with 1,782 requiring hospitalization and 178 becoming severe cases. Based on this projection, Takahashi et al. (2020) estimate that the peak cumulative number of cases nationwide would be 426,482, with 225,024 requiring hospitalization and 7,557 being classified as severe cases. They present prefecture-level data on bed capacity as a reference material regarding the number of patients who could be treated in each prefecture. As mentioned earlier, Japan's health care delivery system was not sufficiently equipped to seamlessly treat COVID-19 patients, but this does not mean that no preparations were made. The confusion surrounding COVID-19 treatment in Japan stems from the mismatch between the country's pre-existing infrastructure for responding to infectious diseases and the treatment capacity required for COVID-19. It also stems from the fact that while the statistical number of hospital beds was substantial, those capable of treating COVID-19 were limited. Next, we explain Japan's pre-COVID-19 infectious disease control system in detail.

Japan established the Communicable Disease Prevention Law in 1897 to address infectious diseases. This law was primarily enacted to combat tuberculosis, which was ravaging the population as a national epidemic. As part of this initiative, the national government established tuberculosis sanatoriums throughout the country. As of 2025, Japan has 140 national hospitals, whose origins can be traced back to pre-World War II army and navy hospitals and said tuberculosis sanatoriums. However, given the limitations of medical science in the first half of the 20th century, which made tuberculosis treatment challenging, the primary objective was to minimize mortality rates. This resulted in social defense measures that, in some respects, disregarded patients' human rights. Consequently, even in national tuberculosis sanatoriums, isolation took precedence over treatment. Furthermore, as national tuberculosis sanatoriums alone were insufficient, municipalities were tasked with preparing isolation facilities. Infectious disease and tuberculosis beds in Japan are predominantly found in national and municipal hospitals due to the necessary involvement of both national and local governments in tuberculosis treatment during the first half of the 20th century. Thus, medical facilities for infectious diseases have primarily been national and municipal hospitals, with a historical emphasis on isolation over treatment. Crucially, university-affiliated hospitals generally do not handle infectious disease treatment (isolation). Rather, with their relatively abundant specialized staff and material resources, they focus on providing highly acute care and treatment for rare diseases while conducting medical professional education and clinical research. Accepting both infectious disease patients for isolation and providing highly acute care and treatment for rare diseases increases the risk of hospital-acquired infections. For this reason, university-affiliated teaching hospitals have not actively accepted infectious disease patients.

Under the previously described infectious disease control system, Japan confronted the COVID-19 pandemic. Although Japan experienced relatively low mortality rates from COVID-19 (from Q1 2020 through Q4 2022, quarterly deaths per million population never exceeded 200. By contrast, in other G7 nations like Germany, France, Italy, the UK, and the United States, quarterly deaths per million exceeded 500; Masuhara and Hosoya, 2025). This prevented significant international attention being paid to Japan's problems, while the mismatch between pre-established systems and the practical limitations of COVID-19-capable hospital beds created significant challenges within Japan. First, Nishiura's (2020) projections exceeded Japan's existing infectious disease bed capacity, revealing an insufficient number of beds capable of isolating COVID-19 patients. Furthermore, even if the bed capacity had been adequate, when COVID-19 cases became severe, they required intensive treatment utilizing ventilators and extracorporeal membrane oxygenation (ECMO). However, infectious disease beds primarily designed for isolation lacked ICU-equivalent capabilities, which made effective treatment difficult in practice. Essentially, Japan's pre-existing infectious disease control measures, which emphasized isolation over treatment, proved inadequate for addressing COVID-19, a highly transmissible disease requiring ventilator and ECMO treatment for severe cases. This revealed a fundamental mismatch between the preparedness measures established under the Infectious Diseases Act and the requirements for managing the pandemic.

When treating patients in beds reserved for infectious disease proved impossible, the only alternative was to use general beds, which presented additional challenges. Among such beds in Japan, those with ICU-equivalent functionality were limited, while beds capable of treating moderate cases were surprisingly scarce. Of the 887,847 general beds (approximately 731 per 100,000 population), only 5,896 were ICU beds, and 6,427 were emergency care beds (both figures from FY2018), which amounted to just 9.90 beds per 100,000 population.[7] This capacity could not accommodate the projected daily peak of 178 severe cases per 100,000 population. Even if one was to expand the scope to include "advanced acute care beds" capable of treating moderate (and sometimes severe) cases of COVID-19, Japan had only approximately 158,000 such beds

[7] Ogata (2022) highlights that Japan had few hospital beds that could be utilized as ICUs or for highly acute care. While there were many hospitals and hospital beds, the author notes that most of them—particularly private hospitals—had become facilities primarily for elderly care and were relatively less capital-intensive than those in other countries. Furthermore, Ogata (2022) provides a rough estimate that only approximately 300,000 beds, or approximately 20% of the total 1.53 million hospital beds, could be used for COVID-19 treatment.

(126.91 per 100,000 population).[8] This fell far short of the capacity required to accommodate the projected peak of 1,782 hospitalized patients per 100,000 population per day. Additional problems included shortages of health care professionals specialized in infectious diseases and insufficient operational staff for ventilators and ECMO equipment, let alone shortages of the equipment itself.

A further complication arose from the fact that ICUs and advanced acute care beds, while categorized as general beds, were not legally required to implement infectious disease control measures under the Medical Care Act. Additionally, these facilities primarily featured four-person rooms rather than private rooms. According to Edamatsu et al. (2021), this arrangement created significant challenges as admitting a COVID-19 patient would necessitate an entire four-person room being used for a single patient. Moreover, wards that accepted COVID-19 patients could not simultaneously treat non-COVID-19 patients as an infection control measure, which required the physically separating patients (for example, using different floods). As a result, Japan's effective treatment capacity was reduced to approximately 39,500 beds (the number of advanced acute care beds divided by four), or approximately 31.73 beds per 100,000 population. Under these circumstances, hospitals capable of treating COVID-19 patients, especially moderate to severe cases, were severely limited, which forced RMCSHs to assume a central role. These institutions were relatively large by Japanese standards, possessed ICUs and advanced acute care beds capable of treating moderate and severe cases, and often had experience in infectious disease control measures dating back to the tuberculosis era. This all resulted in medical staff with comparatively more training in infection control. Perhaps most importantly, many RMCSHs were national or municipal institutions, which made it easier for prefectural governments to request their assistance in treating COVID-19 patients. In the following paragraph, we explain the treatment system that was established after COVID-19 began to spread in 2020.

[8]Based on data from the Ministry of Health, Labour and Welfare: https://www.mhlw.go.jp/stf/wp/hakusyo/kousei/20/backdata/7-2-1.html

On March 1, 2020, in response to a projected potential surge in severe cases, Japan modified its policy to permit the use of general hospital beds in addition to infectious disease beds for treating COVID-19. It also established home rest and recuperation as the standard approach for asymptomatic infected individuals. This represented a significant policy shift compared with February 2020, when the policy had relied on isolation and treatment in infectious disease beds—a principle quickly abandoned following Nishiura's (2020) projections. On March 26, the government directed prefectures to designate "Priority Medical Institutions" that would accept COVID-19 patients on a ward-by-ward basis. National and municipal hospitals and public institutions (e.g., Red Cross hospitals, many of which are also RMCSHs) that possessed infectious disease beds or had been designated under pandemic planning for novel influenza strains (e.g., MERS or SARS) were designated as Priority Medical Institutions. In some cases, national and municipal hospitals without infectious disease beds and other hospitals were also selected as such institutions. Additionally, the government established "Cooperative Medical Institutions" to accommodate suspected cases in dedicated private rooms until a definitive COVID-19 diagnosis could be made. By June 19, 2020, the Ministry of Health, Labour and Welfare unveiled the framework for Japan's COVID-19 treatment system. Prefectures would request "reserved beds" for COVID-19 inpatient treatment from among the aforementioned Priority and Cooperative Medical Institutions. This system positioned prefectural governments as the primary entities that reserve hospital beds for treating COVID-19 inpatients. Furthermore, the reserved beds were categorized as "immediately available beds" (those kept vacant and ready to accept patients upon request) or "standby beds" (those available approximately a week after a request). The proportion of immediately available to standby beds is adjusted according to the status of the COVID-19 outbreak.

To ensure that severe COVID-19 patients were smoothly accommodated during outbreaks, hospitals needed to maintain reserved beds that were not necessarily in active use. However, these beds represented a potential revenue loss for hospitals as they would generate no income unless occupied by COVID-

19 patients. This created minimal incentive for hospitals to maintain reserved beds. Furthermore, Japan's predominant four-person room configuration compounded the financial impact, as allocating one bed for a COVID-19 patient necessitated keeping the remaining three beds vacant for infection control purposes, which significantly reduced revenue. The Japanese government established a "bed reservation fee" subsidy in April 2020 to provide hospitals with incentives to maintain reserved beds. While hospitals received medical fee reimbursements (set at 2–3 times the normal rates) based on length of stay when treating COVID-19 patients, the bed reservation fee compensated for opportunity costs incurred when beds remained empty or unused, which prevented them from accommodating non-COVID-19 patients. Specifically, from May 2020, Priority Medical Institutions received 301,000 yen per bed per day for ICU beds and 52,000–71,000 yen per bed per day for non-ICU general beds (university-affiliated hospitals received even higher bed reservation fees). Cooperative Medical Institutions also received 52,000 yen per bed per day for general beds. In summary, Japan's inpatient medical care system for COVID-19 operated through prefectural governments requesting hospitals to establish reserved beds, accompanied by subsidies for maintaining these beds, whether vacant or unused. This structure was designed to offset the financial disincentives that hospitals would face by dedicating resources to the pandemic response.

4. Sample and data

We use the "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients" published by Japan's Ministry of Health, Labour and Welfare as data for understanding COVID-19 hospitalization rates. This dataset, published monthly from December 1, 2021 (biweekly during February and March 2022), provides hospital-specific information on reserved beds, immediately available beds, and COVID-19 patient hospitalization numbers. Furthermore, it is closely connected to the aforementioned evolution of bed reservation fees. Therefore, we now explain the data while reviewing the COVID-19 outbreak situation in Japan.

In Japan, COVID-19 variants evolved through Alpha (fourth wave, spring 2021), Delta (fifth wave, summer 2021), and Omicron (from January 2022 onward). The Delta variant caused particularly significant social issues. During the summer of 2021, coinciding with the Tokyo Olympics, Japan experienced an explosive increase in Delta variant cases. Meanwhile, metropolitan areas faced two prominent issues highlighted by the media—namely "medical refugees" and "ghost beds." In response to prefectural requests, hospitals established reserved beds for COVID-19 patients and received daily subsidies of 52,000–71,000 yen (they received more for using ICU beds), even when the beds remained empty or unused. However, suspicions arose that some hospitals might have collected these subsidies without accepting patients who required hospitalization (Edamatsu et al., 2021). While medical staff shortages caused by the management of severe cases certainly contributed to hospitals' inability to accommodate patients, some hospitals ultimately could not accept patients. Additionally, the government failed to establish precise rules for subsidy reimbursement when hospitals could not do so, while there were also undeniable discrepancies in the subsidy amounts and overall design of the system.

In response to the issue of ghost beds, on December 1, 2021, the government began to publish hospital-by-hospital data on the actual utilization of reserved beds and immediately available beds. While the government had been tracking this utilization data within their system, it refrained from publication until December 2021 out of privacy concerns—particularly for hospitals with only one COVID-19 patient, where patient identification might be possible—and out of consideration for treatment facilities. However, due to concerns about fraudulent subsidy claims and increasing social pressure, the government proceeded with publication on December 1, 2021, which took the form of the aforementioned "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients." Consequently, data before December 2021 remain unpublished. Nevertheless, this does not significantly impede an analysis of the Omicron variant. In Japan, COVID-19 had largely subsided by December 2021, with nationwide hospitalization numbers in the tens. In January 2022, the Omicron variant spread rapidly, hospitalizations increased, reached their peak in February 2022, and then subsided in March. Therefore, the available data remain sufficient for analyzing hospitalization patterns during the Omicron wave. Additionally, from January 2022 onward, the bed reservation fee structure was modified to include penalties for moral hazard. Thus, the data for the period from January 2022 onward—the focus of this research—are less susceptible to the issue of ghost beds.

The aforementioned "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients" provides data on bed counts and hospitalization numbers designated for COVID-19 without additional information. We also use the "Hospital Functional Report" (Ministry of Health, Labour and Welfare) to supplement hospital attributes. This statistical survey is an annual census that employs questionnaires to collect data on the utilization patterns of hospital wards. It gathers information on ward-level functions (advanced acute, acute care, recovery, and chronic care), nursing staff numbers, health care worker counts, and the application status of additional medical fee reimbursements under the health care payment system—typically on an annual basis, though some data are collected monthly. Furthermore, it provides information on founding entities, addresses, total beds, approval status as specialized function hospitals or RMCSHs, designation status as DRG-PPS medical institutions, and medical equipment inventories. We create a dataset for this analysis by merging hospital attribute variables from the "Hospital Functional Report" with the COVID-19 hospitalization data from the "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients."

Based on hospital functionality, we extract RMCSHs that likely have similar COVID-19 acceptance patterns. Regarding the founding entities, we categorize hospitals into publicly owned hospitals (national/municipal)—which historically handled infectious disease treatment pre-COVID-19 and would find it difficult to refuse prefectural hospitalization requests—and non-governmental hospitals (e.g., Red Cross, agricultural cooperative, and private hospitals). Ta-

Table 2: Ownership types of RMCSHs with beds reserved for COVID-19

	Number of Hospitals	(%)
Publicly owned hospitals		
National hospitals	108	16%
Municipal hospitals	239	35%
Non-governmental hospitals		
Red Cross, Agricultural cooperatives, etc.	144	21%
Other NGOs	196	29%
Total	687	100%

Note: Based on data as of January 19, 2022.

ble 2 presents the distribution of RMCSHs with reserved beds for COVID-19 by founding entity. Of the 707 RMCSHs, 687 hospitals (97.1%) maintained reserved beds for COVID-19 patients. According to the founding entity composition, national hospitals account for 15.7% and municipal hospitals for 34.8%, totaling 50.5%. Regarding non-governmental hospitals, Red Cross and agricultural cooperative hospitals account for 21.0%, while other NGOs account for 28.5%, totaling 49.5%. RMCSHs, which by definition have 200 or more total beds and serve core regional medical functions, represent large-scale health care facilities in Japan, with their founding entities being almost evenly split between publicly owned and non-governmental hospitals.

Since COVID-19 spreads more rapidly with increased human contact density, infection patterns differed between metropolitan and non-metropolitan areas in Japan. Therefore, in addition to the founding entities of RMCSHs, we incorporate an urban versus non-urban layer into our analysis, which enables us to analyze acceptance patterns by the founding entity of RMCSHs while controlling for infection conditions. We employ two distinct layers to differentiate urban and non-urban areas. The first layer (Layer 1) classifies regions as “metropolitan areas” versus “non-metropolitan areas” using secondary medical care zone codes. The former includes major cities with populations that exceed 1 million that experienced high COVID-19 case numbers (Tokyo’s 23 wards, Yokohama, Kawasaki, Saitama, Chiba, Osaka, Kobe, Kyoto, Nagoya, Sapporo, Sendai, Hiroshima, Fukuoka, and Kitakyushu), as well as Naha, which, despite having a population under one million, experienced high case numbers and bed shortages. The latter encompasses all other regions. We verify that in the former areas where COVID-19 bed shortages occurred, differences in hospitalization numbers by founding entity should have been minimal.

Our second layer (Layer 2) identifies hospitals based on whether at least one other RMCSH exists within a 10-km radius (determined by calculating the latitude and longitude based on addresses) versus hospitals with no other RMCSH in their vicinity.[9] Unlike Layer 1, Layer 2 includes prefectural capitals with large populations and other major cities. Across Japan's total area of 378,000 km^2 (of which 27.3% is habitable land), there are 707 RMCSHs, which equals an average of one RMCSH per 534.65 km^2 (or one per 145.96 km^2 of habitable land). Based on habitable land, this translates to approximately one RMCSH within a 12-km radius on average. However, considering that metropolitan areas have higher population densities and consequently more RMCSHs, we classify hospitals based on whether another RMCSH exists within a 10-km radius. If other RMCSHs exist nearby, then role differentiation may create differences in patient acceptance patterns according to the founding entity.

An important consideration must be noted regarding these two layers. The classification is not based strictly on population density, as multiple RMCSHs do not exist in sparsely populated areas; therefore, we designate these categories as "multiple RMCSH (high-population density)" regions and "single RMCSH (low-population density)" regions. Layer 2 employs a criterion of a 10-km radius to distinguish whether multiple RMCSHs exist; thus, it places greater emphasis on the magnitude of "regional population size" or "population density."

While Layer 1 is primarily limited to major metropolitan areas with populations that exceed 1 million—essentially whether an area is a "metropolitan area"

[9]As a complement to Layer 2, we also analyze hospitals located in areas with two or more RMCSHs within a secondary medical care area and those located in areas with only one RMCSH (Layer 2′), the results of which are presented in the Online Appendix.

Table 3: Number of hospitals, total beds, and reserved bed ratios according to the two layers

(a) Layer 1

Variables		Mean	
	n	Total beds	Reserved bed ratios (%)
Publicly owned RMCSHs in metropolitan areas	68	433.75	12.385
Non-governmental RMCSHs in metropolitan areas	92	405.446	6.168
Publicly owned RMCSHs in non-metropolitan areas	271	375.059	8.869
Non-governmental RMCSHs in non-metropolitan areas	241	383.145	6.501

(b) Layer 2

Variables		Mean	
	n	Total beds	Reserved bed ratios (%)
Publicly owned RMCSHs in multiple RMCSH regions	254	405.815	9.862
Non-governmental RMCSHs in multiple RMCSH regions	280	399.471	6.202
Publicly owned RMCSHs in single RMCSH regions	80	333.825	8.466
Non-governmental RMCSHs in single RMCSH regions	40	336.175	7.445

Notes: The variable n is the number of observations. Multiple RMCSH regions have another RMCSH within a 10-km radius; single RMCSH regions do not have another RMCSH within a 10-km radius.

with high numbers of COVID-19 cases—it covers only 13 prefectures and excludes 34 prefectural capitals. By contrast, Layer 2 classifies prefectural capitals as multiple-RMCSH (high-population density) regions. This distinction must be carefully considered when interpreting our analysis results. Table 3 presents the distribution of hospitals in the two layers.

Panel a of Table 3 presents the number of hospitals, total beds, and reserved bed ratios by founding entity across metropolitan and non-metropolitan areas, as defined by Layer 1. Since Layer 1 primarily restricts metropolitan areas' to cities with populations that exceed 1 million, the number of hospitals is smaller than that in non-metropolitan areas. However, the total number of beds in metropolitan areas exceed those in non-metropolitan areas, as do reserved bed ratios. Additionally, in metropolitan and non-metropolitan areas, publicly owned hospitals maintain higher reserved bed ratios than non-governmental hospitals, which indicates that they reserved more beds for COVID-19 patients in response to prefectural requests. Panel b of Table 3 presents values by founding entity based on Layer 2, which categorizes hospitals according to whether other RMCSHs exist within a 10-km radius. There are 120 hospitals with no other RMCSH within a 10-km radius, of which publicly owned hospitals account for 80 (i.e., two-thirds). While no substantial differences exist in total beds between founding entities, publicly owned hospitals exhibit a slightly higher reserved bed ratio.

Descriptive statistics are provided in Table 4. The variables below "total beds" are time-invariant, yet the sample size varies across periods. This occurs because although the "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients" represents a complete census, some hospitals occasionally fail to report correctly, which results in missing data for certain months. Consequently, while most hospitals constitute balanced panel data, reporting errors from some hospitals create unbalanced panel data. We analyze COVID-19 inpatients per 100 beds (hereinafter "inpatients per 100 beds") as the outcome variable. Even when we limit the analysis to RMCSHs, total beds vary by hospital (using the maximum operational bed capacity rather than officially registered beds, as some may be inactive). The mean value of inpatients per 100 beds on December 1, 2021, was 0.08 for publicly owned hospitals and 0.058 for non-governmental hospitals. These values indicate extremely low COVID-19 hospitalization rates. Subsequently, in 2022, publicly owned and non-governmental hospitals experienced increased hospitalizations, though the former consistently exhibited higher mean values than the latter.

The number of reserved beds represents the maximum capacity for treating COVID-19 patients requested by prefectural governments. While the possibility exists that hospitals might have accommodated significantly fewer patients than their reserved bed count due to health care worker shortages, several factors—

namely the ghost beds issue during the Delta variant wave in summer 2021, the subsequent publication of the "aforementioned Monthly Report" by the Ministry of Health, Labour and Welfare, and strengthened penalties through substantial reductions in bed reservation fees from 2022 onward—suggest that the ratio of COVID-19 hospitalizations to reserved beds (hereinafter "the reserved bed occupancy rate") should be considered the effective treatment capacity for COVID-19 inpatients. Thus, we employ the reserved bed occupancy rate as an outcome variable. On December 1, 2021, this rate was 0.951% for publicly owned hospitals and 1.137% for non-governmental hospitals; however, it increased rapidly in 2022. Unlike hospitalization numbers, publicly owned hospitals tended to have lower rates than non-governmental hospitals. This phenomenon relates to the background of our hypothesis and is explained in detail in the next section.

5. Results

First, we explain the analytical approach used in this paper. As discussed in Section 2, our outcome variables are derived from the Ministry of Health, Labour and Welfare's "Monthly Report on Reserved Beds, Immediately Available Beds, and Number of Inpatients," specifically COVID-19 inpatients per 100 beds and the reserved bed occupancy rate (i.e., the proportion of COVID-19 inpatients relative to reserved beds). No experimentally controlled data exist that would allow the manipulation of COVID-19 infection conditions according to the hospital ownership type or region; instead, each hospital treated patients from their respective areas in response to administrative requests, and we use observational data that document these actual circumstances. Consequently, it is impossible to randomly allocate hospital ownership types, COVID-19 variant epidemic periods, or numbers of inpatients, thus precluding an analysis under experimental conditions. Furthermore, due to the absence of treatment and control groups, quasi-experimental analytical methods cannot be employed. Nevertheless, the following background existed in Japan.

Background 1: RMCSHs, which serve as core hospitals that provide acute

Table 4: Summary statistics

Variables		Dec 1, 2021		Jan 19, 2022		Feb 2, 2022	
		Publicly owned	Non-governmental	Publicly owned	Non-governmental	Publicly owned	Non-governmental
COVID-19	Mean	0.08	0.058	2.746	2.028	4.76	3.634
inpatients per	SD	0.217	0.166	2.745	2.333	4.196	2.688
100 beds	n	342	333	339	333	337	334
log (COVID-19	Mean	0.063	0.047	1.108	0.933	1.562	1.399
inpatients per 100	SD	0.154	0.126	0.647	0.566	0.609	0.524
beds +1)	n	342	333	339	333	337	334
Reserved bed	Mean	0.951	1.137	30.728	33.151	52.699	63.927
occupancy rate	SD	2.56	3.462	26.816	26.192	32.647	53.472
(%)	n	340	330	338	332	337	334
Total beds	Mean	386.178	389.393	386.832	389.306	387.062	389.527
	SD	140.435	160.33	140.694	160.928	141.033	160.534
	n	342	333	339	333	337	334
Reserved bed	Mean	8.977	5.829	9.575	6.409	9.799	6.581
ratio (%)	SD	8.726	4.082	8.54	4.462	8.823	4.758
	n	342	333	339	333	337	334
Dummy for	Mean	0.202	0.279	0.201	0.276	0.205	0.278
metropolitan area	SD	0.402	0.449	0.401	0.448	0.404	0.449
	n	342	333	339	333	337	334
Dummy for multiple	Mean	0.763	0.881	0.76	0.875	0.762	0.875
RMCSH regions	SD	0.426	0.324	0.427	0.331	0.426	0.331
	n	337	320	334	320	332	321

Variables		Feb 16, 2022		Mar 2, 2022		Mar 16, 2022	
		Publicly owned	Non-governmental	Publicly owned	Non-governmental	Publicly owned	Non-governmental
COVID-19	Mean	5.249	4.185	4.535	3.716	3.199	2.74
inpatients per	SD	4.227	2.75	4.124	2.564	2.667	2.069
100 beds	n	335	333	335	331	335	331
log (COVID-19	Mean	1.658	1.514	1.517	1.418	1.27	1.196
inpatients per 100	SD	0.591	0.523	0.61	0.527	0.569	0.492
beds +1)	n	335	333	335	331	335	331
Reserved bed	Mean	59.784	76.018	50.329	63.713	36.193	48.152
occupancy rate	SD	37.374	92.819	34.915	42.459	21.528	40.634
(%)	n	335	333	335	331	335	331
Total beds	Mean	387.093	388.928	386.83	388.837	387.454	389.979
	SD	140.735	160.401	140.63	160.833	140.669	160.916
	n	335	333	335	331	335	331
Reserved bed	Mean	9.801	6.667	9.834	6.778	9.851	6.767
ratio (%)	SD	8.846	4.829	8.829	4.952	8.827	4.953
	n	335	333	335	331	335	331
Dummy for	Mean	0.206	0.279	0.206	0.278	0.206	0.278
metropolitan area	SD	0.405	0.449	0.405	0.449	0.405	0.449
	n	335	333	335	331	335	331
Dummy for multiple	Mean	0.761	0.875	0.761	0.874	0.761	0.874
RMCSH regions	SD	0.427	0.331	0.427	0.332	0.427	0.332
	n	330	320	330	318	330	318

Notes: SD stands for standard deviation. The variable n is the number of observations.

care in their regions, are required to be established at a rate of one per medical service area of approximately 360,000 people. However, some areas have multiple hospitals of this type, while some have only one and others have none.

Background 2: There are no ownership restrictions on RMCSHs.

Background 3: Inpatient treatment for patients with moderate to severe COVID-19 requires medical management with substantial human and material resources. This necessitates hospitalization at facilities capable of providing acute care.

Background 4: In Japan, designated medical institutions for COVID-19 treatment were established, and prefectural governments requested hospitals that were providing acute care to establish reserved beds.

Background 5: Among RMCSHs, 97.1% established reserved beds, with an overlap occurring between designated medical institutions and RMCSHs.

Background 6: Publicly owned hospitals had infectious disease beds due to historical circumstances. Because they shared the same establishing entity as the administrative authorities, it was easier for the administration to request the establishment of reserved beds and COVID-19 inpatient care from these institutions.

Against these background conditions, we test the following hypotheses, which were stated at the start of the paper:

Hypothesis 1: There are differences in COVID-19 reserved bed implementation between publicly owned hospitals with vertical relationships to administrative authorities and non-governmental hospitals without such relationships.

Hypothesis 2: Based on Background 6, COVID-19 inpatients per 100 beds differ by hospital ownership type.

Hypothesis 3: If Hypothesis 1 holds, under Background 6, reserved bed occupancy rates are equivalent regardless of hospital ownership type.

Hypothesis 4: In metropolitan areas where COVID-19 beds were under strain, there are no significant differences in inpatients per 100 beds or reserved bed occupancy rates by hospital ownership type.

To test our four hypotheses, we first examine the distribution of total beds and the proportion of reserved beds relative to total beds (hereinafter "reserved bed ratio") among RMCSHs by hospital ownership type. Figures 1 and 2 display the distribution of total beds by hospital ownership type for each layer. The blue line represents publicly owned hospitals, the green line represents non-governmental hospitals, and the red line represents both combined.[10] Figure 1 displays the distribution in metropolitan areas with populations over 1 million (plus Naha) and non-metropolitan areas within Layer 1. In the left panel, which depicts metropolitan areas, the distribution of publicly owned hospitals exhibits a trough near 375 beds, suggesting bimodality. In metropolitan areas, differences may exist in the distribution of total beds between publicly owned and non-governmental hospitals, which are confirmed through distribution equivalence testing in a subsequent analysis. By contrast, the distributions of total beds by hospital ownership type are similar in non-metropolitan areas. Figure 2 presents the distribution of total beds by hospital ownership type in Layer 2. Unlike Layer 1 (Figure 1), the left panel of Figure 2 represents densely populated areas. Perhaps due to the larger sample size, differences by hospital ownership type appear to be minimal. Conversely, the right panel represents areas with lower populations, and due to the smaller number of RMCSHs, differences by hospital ownership type are suggested.

Figures 3 and 4 illustrate the reserved bed ratios by hospital ownership type for each layer. According to Hypothesis 1, if administrative authorities strongly

[10]Results from nationwide data without layer stratification are presented in the Online Appendix.

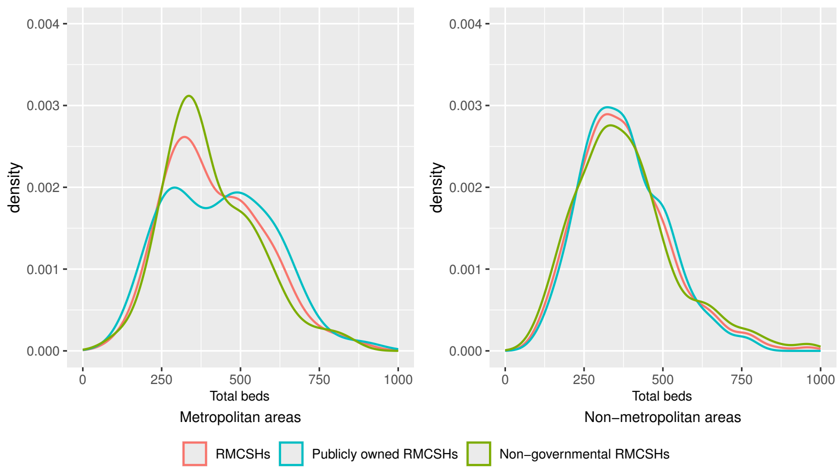

Figure 1: Distribution of total beds by hospital ownership type in Layer 1

requested publicly owned hospitals with vertical relationships to establish beds reserved for COVID-19 patients, then the reserved bed ratios would differ by hospital ownership type. Despite variations across the layers, we confirm that publicly owned hospitals established more reserved beds. This likely reflects Background 6—even among RMCSHs, publicly owned institutions had infectious disease beds due to historical circumstances, and it was easier for the administrative authorities to request their cooperation with the COVID-19 response.

Next, we examine COVID-19 inpatients per 100 beds and the reserved bed occupancy rates in publicly owned and non-governmental hospitals designated as RMCSHs. Figures 5 and 6 illustrate the changing distribution of inpatients per 100 beds (logarithmic values) from January 19, 2022 to March 16, 2022 (December 1, 2021, is omitted due to values clustering at zero). The upper portions of the figures represent publicly owned hospitals, while the lower portions represent non-governmental hospitals. As these are logarithmic values, note the following relationships: $\exp(0.5) - 1 = 0.64$, $\exp(1) - 1 = 1.71$, $\exp(1.5) - 1 = 3.48$, $\exp(2) - 1 = 6.39$, $\exp(2.5) - 1 = 11.18$, and $\exp(3) - 1 = 19.09$. Figure

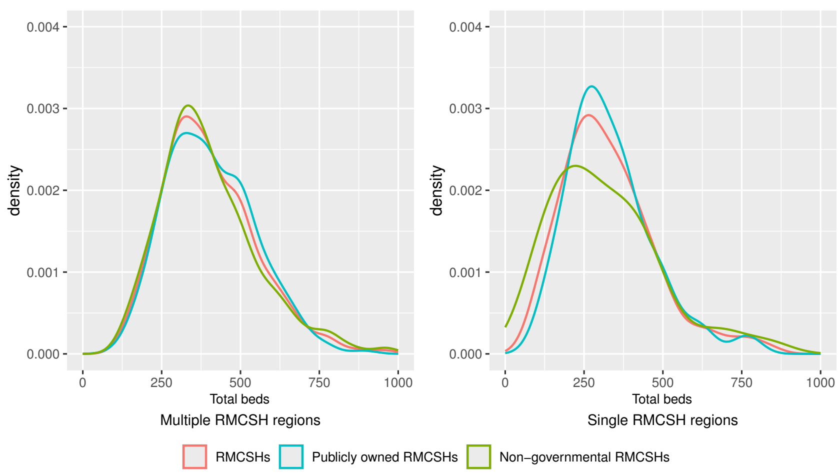

Figure 2: Distribution of total beds by hospital ownership type in Layer 2

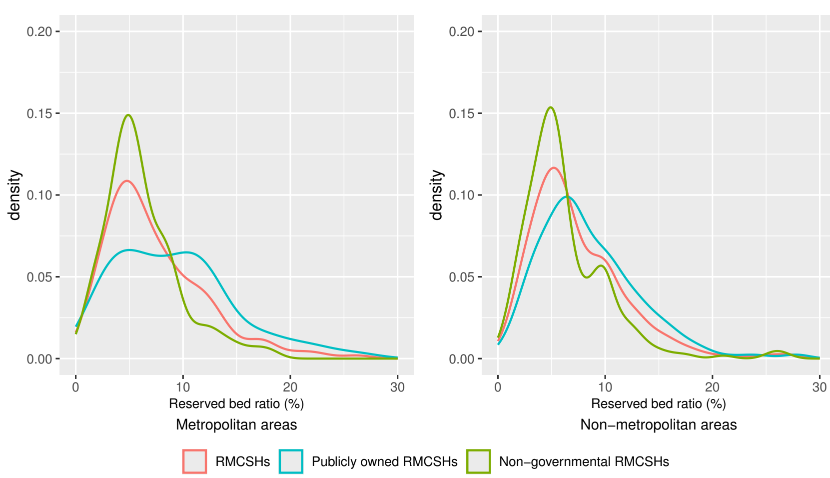

Figure 3: Distribution of reserved bed ratios by hospital ownership types in Layer 1

5 displays inpatients per 100 beds for publicly owned and non-governmental hospitals in metropolitan areas in Layer 1, while Figure 6 displays the same for non-metropolitan areas. Following the intensification of the COVID-19 outbreak in early 2022, the distribution shifted rightward between February 2 and 16. On March 16, the distribution shifted leftward, indicating the subsiding

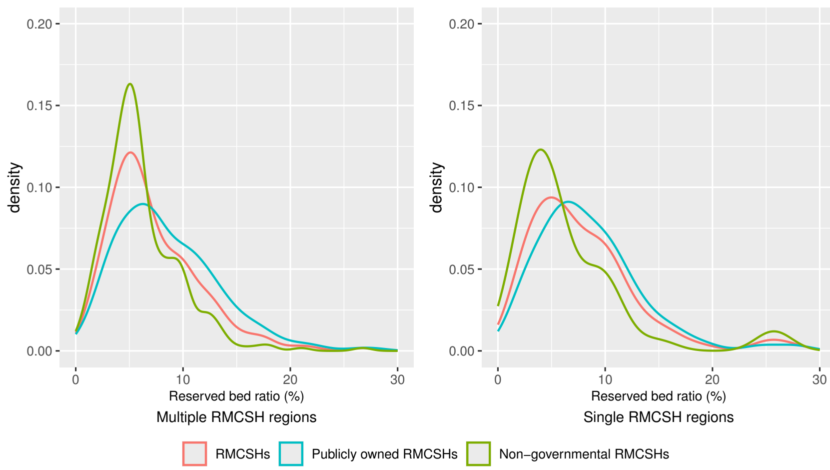

Figure 4: Distribution of reserved bed ratios by hospital ownership types in Layer 2

of the epidemic. Regarding differences by hospital ownership type, except for March 16, the distribution for publicly owned hospitals is positioned further to the right. Although we verify whether this difference is statistically significant through distribution equivalence testing, the observation that publicly owned hospitals appear to have admitted more COVID-19 inpatients is consistent with our intuition when considering Background 6.

An interesting observation is that during the COVID-19 expansion period from February 2 to March 2, no apparent differences existed in distribution peaks between ownership types in metropolitan areas, which serves as evidence that non-governmental hospitals actively admitted COVID-19 inpatients during this period. However, even in metropolitan areas, non-governmental hospitals that accepted more than 10 inpatients per 100 beds (approximately $\exp(2.5)$) were fewer in number than publicly owned hospitals. Conversely, in non-metropolitan areas during the same period, the distribution peak for publicly owned hospitals is positioned slightly to the right, suggesting that differences by hospital ownership type might exist in non-metropolitan areas.

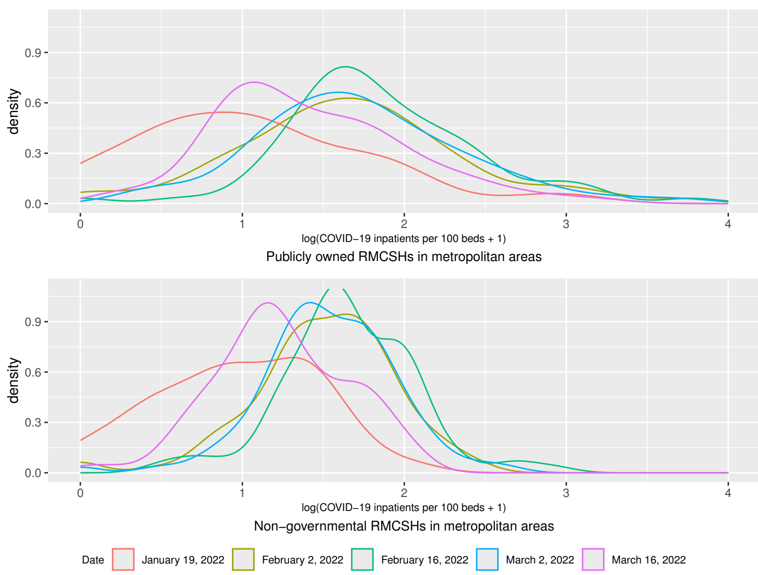

Figure 5: Trends in inpatients per 100 beds in metropolitan areas in Layer 1

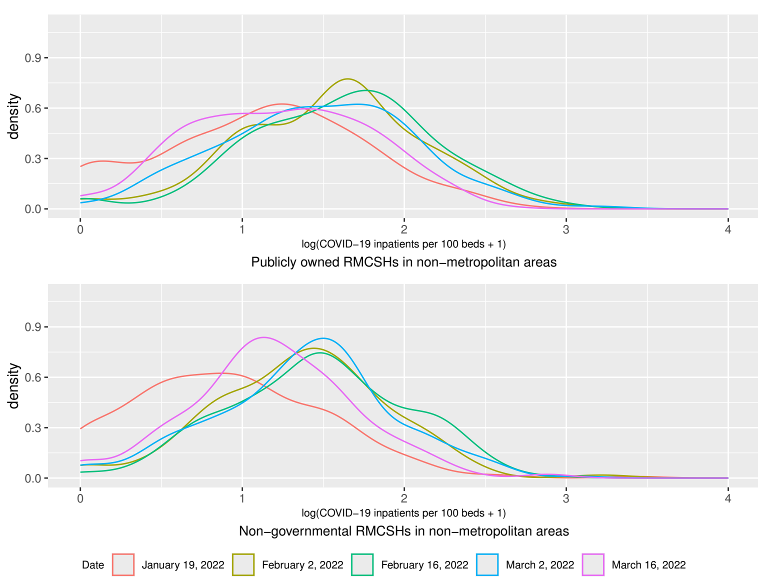

Figure 6: Trends in inpatients per 100 beds in non-metropolitan areas in Layer 1

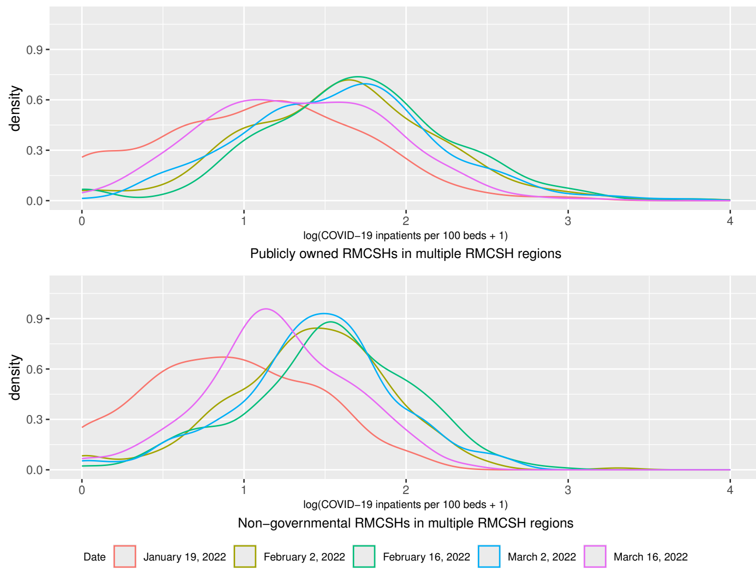

Figure 7: Trends in inpatients per 100 beds in multiple RMCSH regions in Layer 2

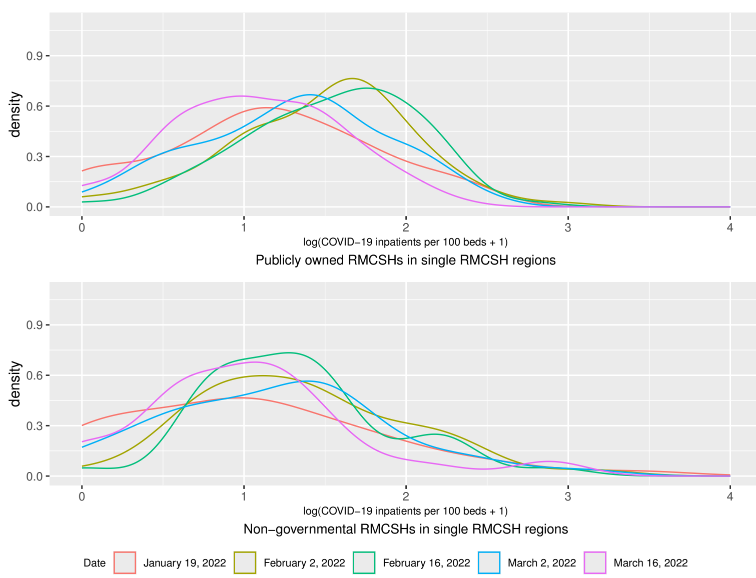

Figure 8: Trends in inpatients per 100 beds in single RMCSH regions in Layer 2

Figure 7 displays the distribution of COVID-19 inpatients per 100 beds in publicly owned and non-governmental hospitals when another RMCSH exists within a 10-km radius. By contrast, Figure 8 displays the distribution when no such hospitals exist. The former observation can be interpreted as regions where hospitals can complement each other in treating inpatients, while the latter observation represents regions where hospitals must manage treatment independently. In Figure 7, when complementary hospitals exist, the distribution peak for publicly owned hospitals is positioned further to the right except for on March 16, while the right tail of the distribution is also thicker. As shown in Figure 8, this tendency remains unchanged even when complementary care is impossible and hospitals had to provide treatment independently; that is, the distribution peak for publicly owned hospitals is still positioned to the right of non-governmental hospitals.

From the discussions of Figures 5 to 8, Japan's publicly owned hospitals accepted many COVID-19 inpatients. By contrast, non-governmental hospitals only played a complementary role—essentially "free-riding"—although this would not be an entirely accurate interpretation. To verify it, we examine our alternative outcome variable, namely the reserved bed occupancy rate. Figures 9 and 10 present the temporal trends in reserved bed occupancy rates in Layer 1, with publicly owned hospitals in the upper panels and non-governmental hospitals in the lower ones. Several observations can be made: First, in non-metropolitan areas, the distribution of reserved bed occupancy rates on January 19 was similar between ownership types; and second, during the increase in COVID-19 cases, the distribution of non-governmental hospitals was sometimes positioned further to the right. Similar trends are observed in Figures 11 and 12 for Layer 2: While publicly owned hospitals tended to admit more inpatients, from the perspective of reserved bed occupancy rates, non-governmental hospitals sometimes exhibited higher rates. As mentioned in Background 6, prefectural governments requested publicly owned RMCSHs to accept many COVID-19 inpatients; however, this was possible because they had also asked these hospitals to establish numerous reserved beds. This suggests that the ob-

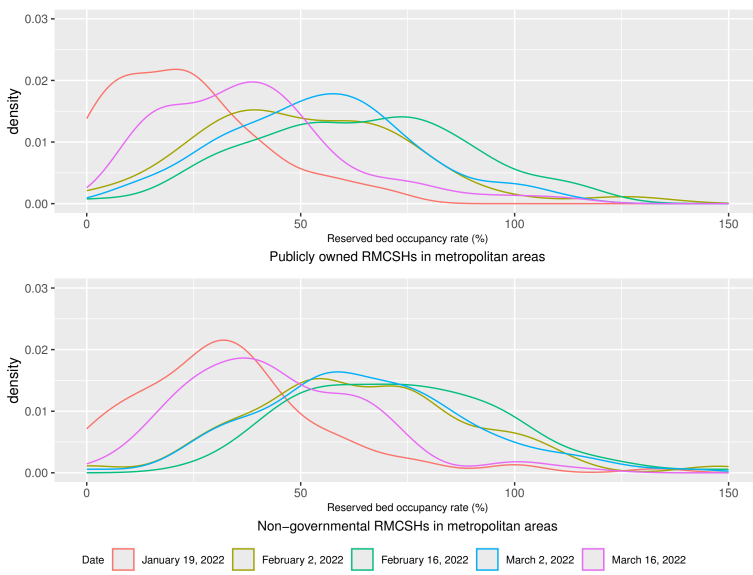

Figure 9: Trends in reserved bed occupancy rates in metropolitan areas in Layer 1

served differences were not due to behavioral variations between ownership types but rather based on the vertical relationships between prefectural governments and hospital ownership.

Our observations derived from Figures 1 through 12 are based on a visual analysis, and while they are intuitive insights, they lack statistical rigor. If beds reserved for treating COVID-19 patients in RMCSHs in similar locations were determined independently of vertical relationships with administrative authorities, then the distribution of such beds would not depend on ownership type and would follow identical distributions. Similarly, if each hospital accepted COVID-19 inpatients independently of any vertical administrative relationships, the resulting number of inpatients per 100 beds would follow identical distributions. Furthermore, the proportion of COVID-19 inpatients to reserved beds as an outcome would also follow identical distributions regardless of the hospital ownership type.

To verify whether the distributions follow the same pattern, we employ the

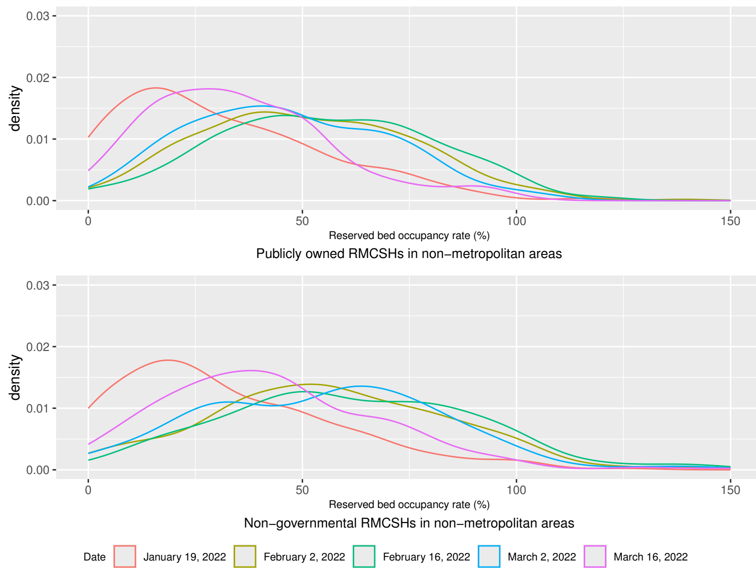

Figure 10: Trends in reserved bed occupancy rates in non-metropolitan areas in Layer 1

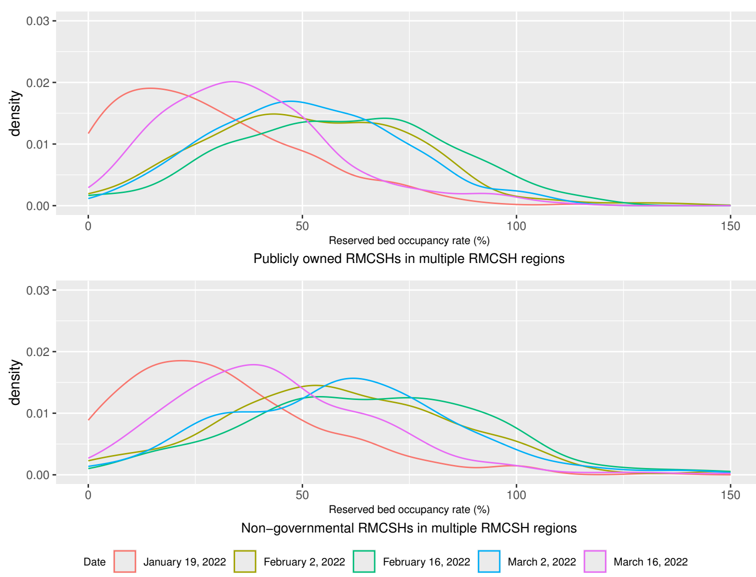

Figure 11: Trends in reserved bed occupancy rates in multiple RMCSH regions in Layer 2

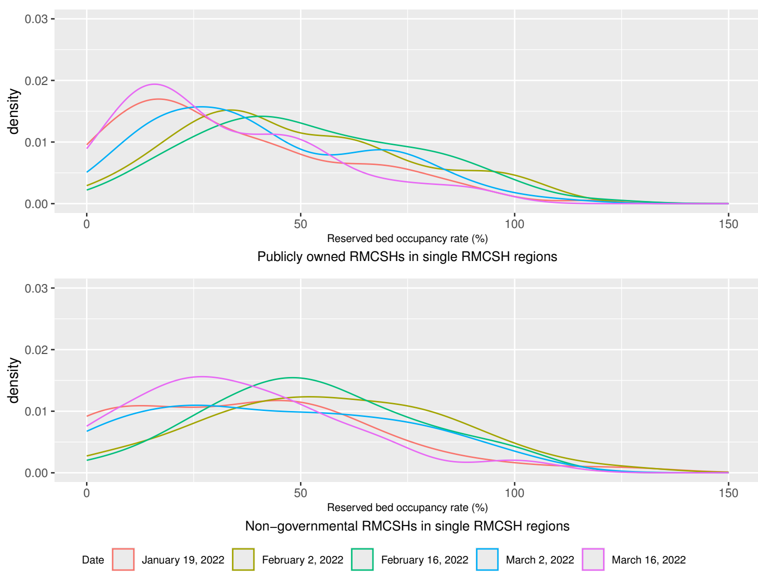

Figure 12: Trends in reserved bed occupancy rates in single RMCSH regions in Layer 2

nonparametric test for density equality proposed by Li (1996, 1999).[11] Let Y_m, $m = 1, 2$, be a random variable, y_m its observed values, $f_m(Y_m)$ the probability density function that Y_m follows, and n_m, $i = 1, \ldots, n_m$, the sample size, which can be described as follows:

$$f_m(y_{mi}) = \sum_{j=1}^{n_m} \frac{1}{n_m h_m} K\left(\frac{y_{mi} - y_{mj}}{h_m}\right). \tag{1}$$

Here, $K(\cdot)$ is a kernel and a density function that satisfies regularity conditions (Li and Racine, 2006, p. 9), such as the existence of a symmetric distribution and finite second derivatives. Usually, the standard normal distribution or the Epanechnikov kernel is used. Additionally, h_m is the parameter of bandwidth, which represents deviation. Under this formulation, the distribution can be interpreted as a finite mixture distribution with n_m components, where the

[11] Masuhara and Hosoya (2023a) analyze the behavioral changes that result from Japan's food service voucher policy during the COVID-19 period by employing nonparametric equivalence and independence tests.

center of each elemental density exists for all samples, and the parameter h_m specifies the shape of the distribution. When the sample size is small, the value of h_m becomes large; however, it constructs a smooth distribution, and sometimes even a multimodal one. As the sample size increases, h_m converges asymptotically to zero while remaining smooth. Since each sample functions as a mean parameter of the symmetric distribution, and the parameter for deviation is common to all samples, any distribution can be estimated to be a smooth density function. For details on nonparametric estimation, see Pagan and Ullah (1999), Li and Racine (2006), and Henderson and Parmeter (2015).

The equality test that specifies $f_1(y_1)$ and $f_2(y_2)$ tests the null hypothesis of $H_0 : f_1(y_1) = f_2(y_2)$ against the alternative hypothesis of $H_1 : f_1(y_1) \neq f_2(y_2)$, using the fact that the following statistic follows a standard normal distribution. Here, $\{y_{1i}\}$ and $\{y_{2i}\}$ are observed values with sample sizes of n_1 and n_2, following $f_1(Y_{1i})$ and $f_2(Y_{2i})$, respectively. Denoting the estimators from (1) with a hat as $\widehat{f}_1(y_1)$ and $\widehat{f}_2(y_2)$, the test statistic for the equality of distributions is described as follows:

$$\widehat{T}_n^{\text{equ}} = \left(n_1 \widehat{h}_1 n_2 \widehat{h}_2\right)^{1/2} \frac{\widehat{\text{ISE}}_n^{\text{equ}}}{\widehat{\sigma}_n^{\text{equ}}} \xrightarrow{\text{d}} \mathcal{N}(0,1), \tag{2}$$

where

$$\begin{aligned} \text{ISE}_n^{\text{equ}} =& \frac{1}{n_1(n_1-1)\widehat{h}_1} \sum_{i=1}^{n_1} \sum_{j=1, j\neq i}^{n_1} K\left(\frac{y_{1i}-y_{1j}}{\widehat{h}_1}\right) \\ &+ \frac{1}{n_2(n_2-1)\widehat{h}_2} \sum_{i=1}^{n_2} \sum_{j=1, j\neq i}^{n_2} K\left(\frac{y_{2i}-y_{2j}}{\widehat{h}_2}\right) \\ &- \frac{1}{n_1(n_2-1)\widehat{h}_2} \sum_{i=1}^{n_1} \sum_{j=1, j\neq i}^{n_2} K\left(\frac{y_{1i}-y_{2j}}{\widehat{h}_2}\right) \\ &- \frac{1}{n_2(n_1-1)\widehat{h}_1} \sum_{i=1}^{n_2} \sum_{j=1, j\neq i}^{n_1} K\left(\frac{y_{2i}-y_{1j}}{\widehat{h}_1}\right), \end{aligned} \tag{3}$$

$$
\begin{aligned}
\left(\widehat{\sigma}_n^{\mathrm{equ}}\right)^2 =2 \Bigg[& \frac{1}{n_1\left(n_1-1\right)\widehat{h}_1} \sum_{i=1}^{n_1} \sum_{j=1, j\neq i}^{n_1} K^2\left(\frac{y_{1i}-y_{1j}}{\widehat{h}_1}\right) \\
& + \frac{1}{n_2\left(n_2-1\right)\widehat{h}_2} \sum_{i=1}^{n_2} \sum_{j=1, j\neq i}^{n_2} K^2\left(\frac{y_{2i}-y_{2j}}{\widehat{h}_2}\right) \\
& + \frac{1}{n_1\left(n_2-1\right)\widehat{h}_2} \sum_{i=1}^{n_1} \sum_{j=1, j\neq i}^{n_2} K^2\left(\frac{y_{1i}-y_{2j}}{\widehat{h}_2}\right) \\
& + \frac{1}{n_2\left(n_1-1\right)\widehat{h}_1} \sum_{i=1}^{n_2} \sum_{j=1, j\neq i}^{n_1} K^2\left(\frac{y_{2i}-y_{1j}}{\widehat{h}_1}\right) \Bigg].
\end{aligned} \tag{4}
$$

If the null hypothesis is not rejected, then the two random variables are not generated from different distributions, and the distributions would be equivalent. In other words, there would be no substantial evidence to refute the distributions' equivalence. This test can also be interpreted as a generalization of the Kolmogorov–Smirnov (KS) test but with improved efficiency. An example where the distribution equality test is used as an extension of Quah (1993b,a) uses the Penn World Table (PWT) version 7.0 (see Summers and Heston, 1991) and is presented in Henderson and Parmeter (2015, pp. 108–109). It tests the equality of output per worker. The test statistic for the distribution of gross domestic product per worker in 1960 and 2005 results in a p-value of 0.002 (Henderson and Parmeter, 2015, p. 109, Table 4.2). The authors' analysis reveals a significant difference between the distributions of per-capita output in 1960 and 2005. For the same data, the p-value for the distribution of per-capita output between OECD and non-OECD countries is 0.000. Therefore, the null hypothesis is rejected by the nonparametric equality test, which means that the two data-generation processes differ. Thus, structural changes cannot be ruled out.

In the present study, when the null hypothesis can be rejected, this indicates a significant difference in COVID-19 inpatients per 100 beds between publicly owned and non-governmental hospitals, which suggests differences based on the founding entity. In other words, it provides evidence to support claims regarding vertical relationships with administrative bodies. Conversely, when no

Table 5: Results of equality tests for the total numbers of beds by hospital ownership type

Publicly owned RMCSH v.s. Non-governmental RMCSH		p-value	KS's p-value
Layer 1	Metropolitan	0.055	0.195
	Non-metropolitan	0.411	0.664
Layer 2	Multiple RMCSH regions	0.472	0.536
	Single RMCSH regions	0.081	0.364

Note: KS stands for Kolmogorov–Smirnov test.

significant difference is found, we cannot conclude that the distributions differ regardless of the founding entity. This suggests the possibility of an inpatient distribution independent of vertical relationships with administrative bodies.

Table 5 summarizes the results of the equality test for the total bed distribution by founding entities in Layers 1 and 2, corresponding to Figures 1 and 2. In addition to the p-values from the distribution equality test, those from the KS test are also included. As shown in Table 5, none of the results are rejected at the 5% significance level. Therefore, regarding Layers 1 and 2, we conclude that no differences exist in the distribution of bed numbers based on the founding entity.

Table 6 summarizes the results of equivalence tests for the distributions of reserved bed ratios (%) by the founding entity of hospitals in Layers 1 and 2, and it corresponds to Figures 3 and 4. At the 5% significance level, all test results in Table 6, including the KS test, are significant. This indicates that the reserved bed ratios differed between publicly owned and non-governmental hospitals according to their founding entity. In other words, such hospitals demonstrate different approaches to the reservation of hospital beds, which confirms Hypothesis 1. As mentioned under Background 6, these test results suggest that it was easier to request reserved beds from publicly owned hospitals with vertical relationships with the administration.

Table 7 presents the results of equivalence tests for COVID-19 inpatients per 100 beds by founding entity for Layers 1 and 2, corresponding to Figures 5 to 8

Table 6: Results of equality tests for reserved bed ratios by hospital ownership type

Publicly owned RMCSH v.s. Non-governmental RMCSH		p-value	KS's p-value
Layer 1	Metropolitan	0.000	0.000
	Non-metropolitan	0.000	0.000
Layer 2	Multiple RMCSH regions	0.000	0.000
	Single RMCSH regions	0.022	0.004

Note: KS stands for Kolmogorov–Smirnov test.

and Hypothesis 2. Regarding inpatient numbers, we conduct tests monthly to control for COVID-19 expansion and contraction. Panel a presents the results for Layer 1, with the data being divided between metropolitan areas with high COVID-19 cases and non-metropolitan areas with fewer cases. In metropolitan areas, only February 2 and March 2, 2022, are significant at the 5% level, with no significant differences by founding entity observed in the distributions of inpatient numbers during other periods. This confirms that in metropolitan areas with high COVID-19 cases, all hospitals were compelled to accept inpatients regardless of ownership type. Conversely, in non-metropolitan areas, all dates except December 1 exhibit significance at the 5% level, which indicates that distributions differed by founding entity in regions with relatively fewer COVID-19 cases. Panel b of Table 7 presents the test results for Layer 2, with the data being divided based on whether other RMCSHs exist within a 10-km radius. For both categories, the left side showing multiple RMCSH (high-population density) regions is significant at the 5% level for all dates except December 1. By contrast, the right side, which shows single RMCSH (low-population density) regions, exhibits no significant differences except for February 2022.

Summarizing these results in light of Hypothesis 2, we confirm that COVID-19 inpatients per 100 beds differed according to the founding entity of hospitals in areas with multiple RMCSH (high-population density regions). In regions where complementary hospitals exist, we observe differences in approaches to reserved beds between publicly owned and non-governmental hospitals, as shown

Table 7: Results of equality tests for the number of inpatients per 100 beds by hospital ownership type

(a) Layer 1

Publicly owned RMCSH v.s.	Metropolitan		Non-metropolitan	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.078	0.188	0.180	0.995
January 19, 2022	0.108	0.165	0.000	0.000
February 2, 2022	0.015	0.079	0.001	0.000
February 16, 2022	0.064	0.037	0.019	0.003
March 2, 2022	0.018	0.037	0.024	0.014
March 16, 2022	0.201	0.150	0.012	0.091

(b) Layer 2

Publicly owned RMCSH v.s.	Multiple RMCSH regions		Single RMCSH regions	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.255	0.985	0.398	0.139
January 19, 2022	0.001	0.001	0.390	0.467
February 2, 2022	0.001	0.000	0.017	0.048
February 16, 2022	0.007	0.005	0.005	0.005
March 2, 2022	0.000	0.000	0.726	0.763
March 16, 2022	0.004	0.008	0.652	0.595

Note: KS stands for Kolmogorov–Smirnov test.

in Table 6. Since non-governmental hospitals are positioned to the left in the distribution, they did not need to accept inpatients beyond their capacity. While a similar trend was observed in areas with single RMCSH (low-population density) regions, apparent differences only emerged in February. This suggests that when providing treatment alone in a region, even non-governmental hospitals with relatively fewer reserved beds had to accept patients if COVID-19 cases occurred in that area; however, when the spread of COVID-19 became excessive, the circumstances appeared to exceed hospitals' level of preparedness.

Table 8 presents the results of equivalence tests for reserved bed occupancy rates (%) by founding entity, corresponding to Figures 9 to 12 and Hypothesis 3. Panel a presents the results for Layer 1 divided between metropolitan and non-metropolitan areas, with metropolitan areas exhibiting significant differences by the founding entity of hospitals at the 5% level on January 19 and February 2.

Table 8: Results of equality tests for reserved bed occupancy rates by hospital ownership type

(a) Layer 1

Publicly owned RMCSH v.s.	Metropolitan		Non-metropolitan	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.855	0.321	0.832	1.000
January 19, 2022	0.004	0.001	0.959	1.000
February 2, 2022	0.015	0.002	0.075	0.107
February 16, 2022	0.503	0.079	0.097	0.026
March 2, 2022	0.112	0.018	0.001	0.000
March 16, 2022	0.060	0.107	0.004	0.003

(b) Layer 2

Publicly owned RMCSH v.s.	Multiple RMCSH regions		Single RMCSH regions	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.758	0.971	0.233	0.149
January 19, 2022	0.336	0.287	0.165	0.547
February 2, 2022	0.008	0.025	0.356	0.162
February 16, 2022	0.022	0.003	0.686	0.948
March 2, 2022	0.000	0.000	0.103	0.202
March 16, 2022	0.004	0.003	0.122	0.283

Note: KS stands for Kolmogorov–Smirnov test.

In non-metropolitan areas, only March 2 and March 16 are significant at the 5% level. In response to rising case numbers in metropolitan areas, reserved bed occupancy rates showed no significant differences by founding entity, confirming that hospitals admitted inpatients according to their reserved bedscapacities, regardless of ownership. Panel b presents the test results for Layer 2, with the data being divided based on whether other RMCSHs existed within a 10-km radius. For multiple RMCSH (high-population density) regions, significant differences by founding entity emerge from February onward at the 5% level, which indicates that reserved bed occupancy rates differed by founding entity. Conversely, no significant differences by founding entity are observed across all periods in single RMCSH (low-population density) regions where hospitals provided treatment independently.

From the results in Table 8, we confirm Hypothesis 3 in single RMCSH (low-population density) regions, where no notable differences in reserved bed occupancy rates were observed regardless of the founding entity. By contrast, Hypothesis 3 is not confirmed in multiple RMCSH (high-population density) regions, which is attributable to the differences in reserved bed approaches between publicly owned and non-governmental hospitals, as confirmed in Table 6. Non-governmental hospitals had relatively fewer reserved beds and presumably admitted inpatients near or beyond their reserved bed capacity during infection surges.

Finally, from Tables 7 and 8, we evaluate Hypothesis 4 regarding COVID-19 inpatients per 100 beds or reserved bed occupancy rates in metropolitan areas. In metropolitan areas with increased COVID-19 cases, while Table 6 confirms differences in reserved beds between publicly owned and non-governmental hospitals, no differences exist in inpatients per 100 beds according to the founding entity, specifically on February 2 and March 2, 2022. Thus, regarding inpatient numbers during COVID-19 peaks, Hypothesis 4 is largely supported. No significant differences are observed in reserved bed occupancy rates except on January 19 and February 2, 2022, which indicates that publicly owned and non-governmental hospitals utilized beds according to their capacity. This confirms Hypothesis 4, which suggests that other complementary RMCSHs were unavailable to respond to COVID-19 surges in metropolitan areas. Although founding entities differed in their initial numbers of reserved beds, these differences in capacity converged during the peaks.

To verify Hypothesis 4 from another perspective, we examine the independence between (i) reserved bed ratios and COVID-19 inpatients per 100 beds and (ii) between these and reserved bed occupancy rates.[12] Since reserved bed ratios are predetermined based on prefectural requests and hospital treatment capacity, they cannot be frequently modified and effectively become predetermined variables. If (i) remains independent regardless of the founding entity when COVID-19 cases increased, then hospitals had to accept COVID-19 pa-

[12] For independence test statistics, refer to Ahmad and Li (1997), Li and Racine (2006), and Henderson and Parmeter (2015).

Table 9: Independence tests for reserved bed ratios and COVID-19 inpatients per 100 beds

(a) Layer 1

	Metropolitan			Non-metropolitan		
	Both RMCSHs	Publicly owned	Non-governmental	Both RMCSHs	Publicly owned	Non-governmental
December 1, 2021	0.022	0.065	0.024	0.038	0.234	0.350
January 19, 2022	0.000	0.000	0.000	0.000	0.000	0.000
February 2, 2022	0.000	0.000	0.000	0.000	0.000	0.000
February 16, 2022	0.000	0.000	0.000	0.000	0.000	0.000
March 2, 2022	0.000	0.000	0.000	0.000	0.000	0.000
March 16, 2022	0.000	0.000	0.000	0.000	0.000	0.000

(b) Layer 2

	Multiple RMCSH regions			Single RMCSH regions		
	Both RMCSHs	Publicly owned	Non-governmental	Both RMCSHs	Publicly owned	Non-governmental
December 1, 2021	0.000	0.036	0.039	0.282	0.295	0.822
January 19, 2022	0.000	0.000	0.000	0.000	0.001	0.004
February 2, 2022	0.000	0.000	0.000	0.000	0.000	0.000
February 16, 2022	0.000	0.000	0.000	0.000	0.000	0.001
March 2, 2022	0.000	0.000	0.000	0.001	0.034	0.056
March 16, 2022	0.000	0.000	0.000	0.009	0.618	0.021

tients regardless of their reserved bed capacity. If independence (i) holds during COVID-19 surges in Layer 1 metropolitan areas, this would suggest that Japan's COVID-19 treatment capacity was overwhelmed. Realistically, we expect hospitals to have accepted inpatients according to their reserved bed capacity, which would suggest a positive relationship between reserved bed ratios and inpatients per 100 beds, with the independence tests likely being rejected.

Table 9 presents the independence test results for (i) (figures are provided in the Online Appendix due to space constraints). The results are presented for Layers 1 and 2 divided between metropolitan (high population regions) and non-metropolitan (low population regions) areas and further separated by no founding entity division, publicly owned hospitals, and non-governmental hospitals. While independence cannot be rejected in some cases on December 1 and March for both layers, independence is mainly rejected. This confirms that hospitals admitted inpatients according to their reserved bed numbers.

Next, we discuss the results of (ii) the independence between reserved bed

Table 10: Independence tests for reserved bed ratios and occupancy rates

(a) Layer 1

	Metropolitan			Non-metropolitan		
	Both RMCSHs	Publicly owned	Non-governmental	Both RMCSHs	Publicly owned	Non-governmental
December 1, 2021	0.017	0.156	0.026	0.000	0.054	0.164
January 19, 2022	0.104	0.125	0.025	0.002	0.000	0.853
February 2, 2022	0.000	0.026	0.002	0.001	0.039	0.018
February 16, 2022	0.000	0.001	0.000	0.001	0.154	0.055
March 2, 2022	0.000	0.082	0.001	0.001	0.157	0.002
March 16, 2022	0.000	0.008	0.031	0.001	0.474	0.002

(b) Layer 2

	Multiple RMCSH regions			Single RMCSH regions		
	Both RMCSHs	Publicly owned	Non-governmental	Both RMCSHs	Publicly owned	Non-governmental
December 1, 2021	0.000	0.006	0.010	0.181	0.091	0.837
January 19, 2022	0.004	0.001	0.818	0.040	0.109	0.330
February 2, 2022	0.000	0.051	0.003	0.070	0.066	0.556
February 16, 2022	0.000	0.002	0.001	0.028	0.079	0.150
March 2, 2022	0.000	0.059	0.000	0.042	0.503	0.254
March 16, 2022	0.000	0.294	0.000	0.010	0.154	0.391

ratios and reserved bed occupancy rates. If these are mutually independent regardless of the founding entity, then hospitals accepted COVID-19 inpatients (reserved bed occupancy) irrespective of their predetermined reserved bed ratios. However, we expect publicly owned hospitals to have had higher reserved bed ratios due to vertical relationships but lower reserved bed occupancy rates when they accepted inpatients, which would suggest a negative correlation and the likely rejection of independence. However, in metropolitan areas in Layer 1, during increased COVID-19 hospitalizations, if hospitals were forced to accept inpatients due to vertical relationships with prefectures regardless of their predetermined reserved bed ratios, then independence might not be rejected.

Table 10 presents the independence test results for (ii), following the same structure as Table 9, with Layers 1 and 2 divided between metropolitan (high population regions) and non-metropolitan (low population regions) areas and further separated by no founding entity division, publicly owned hospitals, and non-governmental hospitals. In Layer-1 metropolitan areas, independence cannot be rejected for publicly owned hospitals on December 1, January 19, and March 2 (and for all hospitals combined on January 19), which indicates that in some instances, hospitals accepted inpatients regardless of their reserved bed capacity. However, independence was rejected at the 5% significance level in all other cases, which suggests that situations where hospitals were compelled to accept inpatients due to vertical relationships with prefectures were limited. For non-governmental hospitals in metropolitan areas, independence is rejected at the 5% level across all periods, which likely indicates weaker vertical relationships with prefectures. Independence is also generally rejected in Layer-2 regions with other RMCSHs within a 10-km radius. Thus, in high population regions, COVID-19 inpatients per 100 beds and reserved bed occupancy rates cannot be considered to have been random outcomes.

Table 10 also reveals interesting patterns. In non-metropolitan areas of Layer 1 and in Layer 2 where no other RMCSHs existed within a 10-km radius, independence often cannot be rejected. Specifically, independence is rejected at the 5% level only for publicly owned hospitals in Layer 1 on January 19 and February 2 and for non-governmental hospitals in Layer 1 on March 2 and 16. This suggests that in single RMCSH (low-population density) regions, COVID-19 inpatients per 100 beds and reserved bed occupancy rates can be considered random outcomes independent of predetermined reserved beds.

While these results do not provide direct evidence to confirm Hypothesis 4, they do suggest that independence with predetermined reserved beds does not hold in high-population regions. Therefore, we conclude that differences in COVID-19 inpatient treatment between founding entities did exist.

6. Concluding remarks

This study analyzed COVID-19 hospitalization acceptance from December 2021 to March 2022 with a focus on the ownership types of RMCSHs responsible for acute care in Japan. Additionally, two analytical layers that concerned regional characteristics were introduced. We obtained the following conclusions regarding our four hypotheses: First, publicly owned hospitals, which maintain vertical relationships with administrative authorities, differed significantly from non-governmental hospitals in their reserved bed ratios, demonstrating different approaches to reserved beds (Hypothesis 1). Given the historical context, we expected prefectural governments to find it easier to request COVID-19 patient admissions from publicly owned RMCSHs (Background 6), and we confirmed that COVID-19 inpatients per 100 beds differed substantially by hospital ownership type in multiple RMCSH (high-population density) regions and non-metropolitan areas (Hypothesis 2). Conversely, in single RMCSH (low-population density) regions, differences in inpatients per 100 beds by hospital ownership type were observed only in February 2022, with no differences detected in other periods. While Hypothesis 1 was validated and against Background 6, the reserved bed occupancy rates in single RMCSH (low-population density) regions exhibited no significant differences regardless of ownership type, whereas significant differences were observed in multiple RMCSH (high-population density) regions (Hypothesis 3). Finally, regarding Hypothesis 4, in metropolitan areas where the COVID-19 bed capacity was severely strained, significant differences in inpatients per 100 beds by hospital ownership type during COVID-19 expansion periods were observed only on February 2 and March 2, 2022. By contrast, regarding reserved bed occupancy rates, no significant differences were observed between the two groups except on January 19 and February 2, 2022, which indicates utilization patterns consistent with reserved bed capacities.

Additionally, we conducted supplementary analyses to examine the independence between reserved bed ratios (ex ante) and inpatients per 100 beds (ex post), as well as that between reserved bed ratios (ex ante) and reserved bed occupancy rates (ex post). If the former independence had held, then it would have indicated that Japan's COVID-19 treatment capacity had reached its limits, while if the latter independence had held, then it would mean that COVID-19 patient admissions (reserved bed occupancy rates) were accepted regardless of predetermined reserved bed ratio levels. Regarding the former, independence was rejected except on December 1 and in March, which confirmed that patient admissions corresponded to the number of reserved beds. Regarding the latter, independence could not be rejected in single RMCSH (low-population density) regions, which confirmed that inpatients per 100 beds and reserved bed occupancy rates were not outcomes based on predetermined reserved beds but rather reflected situations where hospitals were compelled to accept patients as they arrived.

Based on these findings, the following policy implications emerge regarding Japan's future infectious disease treatment system: First, different approaches to reserved beds should be adopted for multiple RMCSH (high-population density) regions versus single RMCSH (low-population density) regions. When two or more RMCSHs exist within a region, alternatives become available for infectious disease treatment. Functional differentiation (role sharing) would enable the implementation of infectious disease inpatient treatment. However, when only one RMCSH exists in a region, no alternatives are available. In such cases, limiting bed allocation according to ownership type could result in bed shortages simply because the sole RMCSH is not a publicly owned hospital. From an equity perspective, significant disparities in infectious disease treatment based on residential location would be undesirable. During nationwide outbreaks, in its monitoring of infection trends, the government should pay particular attention to single RMCSH (low-population density) regions. In Japan and other countries, particularly stringent infection control measures have been implemented in elderly care facilities. Given the current health care delivery system, regions with only one RMCSH as their primary medical institution would be likely to require similar responses at the regional level.

Second, reserving beds for infectious disease inpatients is crucial. While RMCSHs exhibited similar total bed distributions regardless of their ownership type, reserved bed ratios differed by ownership. Moreover, COVID-19 inpatients (both per 100 beds and occupancy rates) were accepted according to predetermined reserved bed ratios. Hospitals could not accept patients in numbers that substantially exceeded their predetermined reserved bed numbers, and these predetermined beds actually determined regional patient numbers. To ensure complete infectious disease treatment within regions, increasing the number of reserved beds regardless of vertical relationships becomes crucial. Particularly when non-governmental hospitals predominate in a region, treatment systems must be established during peacetime to secure beds without being constrained by vertical relationships. Sufficient communication must be maintained among local governments and non-governmental medical institutions during peacetime, as well as among medical institutions themselves. In this regard, there appears to be much to learn from the Matsumoto Model in Japan's Nagano Prefecture.

Third, regarding treatment systems during infectious disease expansion periods in metropolitan areas, active decisions must be made between prioritizing functional differentiation (role sharing) and maintaining complementary relationships. Overlapping with the first two implications, while metropolitan areas exhibited differences in inpatients per 100 beds, differences in reserved bed occupancy rates were small except at the beginning of expansion periods. Administrative decisions presumably first requested patient admissions from vertically related publicly owned hospitals before approaching non-governmental hospitals as reserved beds filled. This resulted in a treatment system where reserved bed occupancy rates initially differed but subsequently converged, with different numbers of inpatients per 100 beds but no differences in reserved bed occupancy rates. A correlation analysis rejected independence between pre-expansion reserved bed ratios and both inpatients per 100 beds and reserved bed occupancy rates, which indicates that at least some treatment capacity remained available in the data. When infectious disease patient expansion exceeds expectations, smooth transitions from functional differentiation to complementarity become difficult, while complementarity affects the treatment of non–infectious disease patients. Establishing treatment systems may require a hospital consensus regarding functional differentiation and complementarity. Here, too, treatment systems must be planned during peacetime to determine role sharing for ensuring complete treatment within regions.

Unfortunately, information regarding COVID-19 inpatients in Japan, including severity levels and bed types (ICU or not), has not been disclosed due to patient privacy concerns. Additionally, while the government tracked patient admissions before December 2021, these data remain unpublished, which prevented a quantitative assessment of ghost beds during the Delta variant period. However, following the identification of the ghost bed problem, this study has clarified the actual patient admission practices during the Omicron variant period, which confirms dependence on ownership type. While this represents a deviation from rational administrative behavior, its potential impact on regional resident welfare constitutes a crucial consideration for constructing future infectious disease treatment systems. Desirable infectious disease countermeasures must be developed while examining treatment systems in countries other than Japan.

References

Ahmad, I.A., Li, Q., 1997. Testing independence by nonparametric kernel method. Statistics & Probability Letters 34, 201–210. URL: https://doi.org/10.1016/S0167-7152(96)00183-6.

Anan, H., 2022. Review and future prospects of the medical system for COVID-19: Focusing on the efforts of Kanagawa Prefecture (in Japanese). Journal of the National Institute of Public Health (Hoken Iryo Kagaku) 71, 324–334. URL: https://www.niph.go.jp/journal/data/71-4/202271040006.pdf.

Archana Mishra, G., 2020. District administration mulls reducing reserved bed capacity for Covid patients. Hindustan Times Available at: https://www.hindustantimes.com/gurugram/district-administration-mulls-reducing-reserved-bed-capacity-for-covid-patients/story-i3OUqxWXkGhJ6cNGNRdXgI.html (Accessed: May 3rd, 2025).

Barbash, I., Davis, B., Kerlin, M., Admon, A., Costa, D., Vranas, K., Kahn, J., 2024. The relationship between health system affiliation and hospital strategies for COVID-19 preparedness. SSM - Health Systems 2, 100004. URL: https://doi.org/10.1016/j.ssmhs.2023.100004.

Berger, E., Winkelmann, J., Eckhardt, H., Nimptsch, U., Panteli, D., Reichebner, C., Rombey, T., Busse, R., 2022. A country-level analysis comparing hospital capacity and utilisation during the first COVID-19 wave across Europe. Health Policy 126, 373–381. URL: https://doi.org/10.1016/j.healthpol.2021.11.009.

Board of Audit in Japan, 2023. Status of implementation of the project for securing hospital beds for admission of patients with novel coronavirus infection. The report pursuant to the provision 30-2 of the Act of the Board of Audit (in Japanese).

Edamatsu, Y., Goto, K., Ishizuka, H., 2021. COVID-19 bed subsidy boosted hospitals back into the black. The Asahi Shimbun Available at: https://www.asahi.com/ajw/articles/14504436 (Accessed: May 3rd, 2025).

Furuhata, H., Araki, K., 2024. Estimation of the decrease of medical fees by the COVID-19 pandemic and its deterrence by the subsidy for isolation beds (in Japanese). Journal of Health Care and Society (Iryo To Shakai) 34, 91–103. URL: https://doi.org/10.4091/iken.2024.002.

Henderson, D.J., Parmeter, C.F., 2015. Applied Nonparametric Econometrics. Cambridge University Press. URL: https://doi.org/10.1017/CBO9780511845765.

Hijikata, N., Murakami, K., Uehara, S., Shibuya, K., Fukuda, Y., 2024. Characteristics and courses of COVID-19 in patients from the first through fifth waves of the disease: Focused on a single public health center in tokyo, japan (in Japanese). Japanese Journal of Public Health (Nihon Koshu Eisei Zasshi) 71, 117–123. URL: https://doi.org/10.11236/jph.23-077.

Ii, M., Watanabe, S., 2022. The paradox of the covid-19 pandemic: The impact on patient demand in japanese hospitals. Health Policy 126, 1081–1089. URL: https://doi.org/10.1016/j.healthpol.2022.09.005.

Inoue, F., 2024. The efforts of the nursing department of Kawasaki City Tama Hospital against the novel coronavirus infections (in Japanese). The St. Marianna Medical Journal 51, S261–S266. URL: https://doi.org/10.14963/stmari.51.S261.

Kraus, M., Stegner, C., Reiss, M., Riedel, M., Børsch, A., Vrangbæk, K., Michel, M., Turmaine, K., Horváth, K., Túri, G., Dandi, R., Mori, A., Czypionka, T., 2025. Management of hospital care during the COVID-19 pandemic: Lessons learnt from five European countries. SSM - Health Systems 4, 100050. URL: https://doi.org/10.1016/j.ssmhs.2025.100050.

Li, Q., 1996. Nonparametric testing of closeness between two unknown distribution functions. Econometric Reviews 15, 261–274. URL: https://doi.org/10.1080/07474939608800355, doi:10.1080/07474939608800355.

Li, Q., 1999. Nonparametric testing the similarity of two unknown density functions: Local power and bootstrap analysis. Journal of Nonparametric Statistics 11, 189–213. URL: https://doi.org/10.1080/10485259908832780, doi:10.1080/10485259908832780.

Li, Q., Racine, J., 2006. Nonparametric Econometrics: Theory and Practice. 1 ed., Princeton University Press.

Lien, H.M., Chou, S.Y., Liu, J.T., 2008. Hospital ownership and performance: Evidence from stroke and cardiac treatment in taiwan. Journal of Health Economics 27, 1208–1223. URL: https://doi.org/10.1016/j.jhealeco.2008.03.002.

Masuhara, H., Hosoya, K., 2022. Japan's response to the COVID-19 pandemic: Focusing on the healthcare system and human behavior (in Japanese). Journal of Social Security Research (Shakai Hosho Kenkyu) 7, 184–198. URL: https://ipss.repo.nii.ac.jp/records/486.

Masuhara, H., Hosoya, K., 2023a. Relationship among covid-19, mobility, and food service vouchers in japan. Applied Economics 56, 375–397. URL: https://doi.org/10.1080/00036846.2023.2167927.

Masuhara, H., Hosoya, K., 2023b. Supplementary note to Masuhara and Hosoya (2022) (in Japanese). The Kokugakuin University Economic Review 71, 21–78. URL: https://k-rain.repo.nii.ac.jp/records/2000040.

Masuhara, H., Hosoya, K., 2025. Which countries performed better in the covid-19 pandemic? lessons from and for governments. Journal of Policy Modeling forthcoming. URL: https://doi.org/10.1016/j.jpolmod.2025.05.008.

Matsumoto, T., 2021. The way the medical care system should be in the event of a pandemic (in Japanese). The Journal of the Japanese Society of Internal Medicine 110, 2392–2401. URL: https://doi.org/10.2169/naika.110.2392.

Moscelli, G., Gravelle, H., Siciliani, L., Gutacker, N., 2018. The effect of hospital ownership on quality of care: Evidence from England. Journal of Economic Behavior & Organization 153, 322–344. URL: https://doi.org/10.1016/j.jebo.2018.05.009.

Narita, Y., Yata, K., 2024. Algorithm as experiment: Machine learning, market design, and policy eligibility rules. Cowles Foundation Discussion Paper 2391. Cowles Foundation for Research in Economics, Yale University. URL: https://cowles.yale.edu/sites/default/files/2024-05/d2391.pdf.

Nishiura, H., 2020. The 5th meeting of the Advisory Board on Countermeasures to Combat Novel Coronavirus Infections (February 2, 2020) Reference 1 (in Japanese): Materials submitted by Dr. Nishiura. URL: https://www.kantei.go.jp/jp/singi/novel_coronavirus/senmonkakaigi/sidai_r020302.pdf. epidemic scenario for new coronavirus infection (as of February 29).

Ogata, Y., 2022. Covid-19 and regional medical collaboration in Japan (in Japanese). New Medicine in Japan 49, 86–89. URL: https://cir.nii.ac.jp/crid/1520292876037069056.

Okuse, C., 2024. The efforts of Kawasaki City Tama Hospital against the novel coronavirus (in Japanese). The St. Marianna Medical Journal 51, S239–S260. URL: https://doi.org/10.14963/stmari.51.S239.

Pagan, A., Ullah, A., 1999. Nonparametric Econometrics. Themes in Modern Econometrics, Cambridge University Press. URL: https://doi.org/10.1017/CBO9780511612503, doi:10.1017/CBO9780511612503.

Pérotin, V., Zamora, B., Reeves, R., Bartlett, W., Allen, P., 2013. Does hospital ownership affect patient experience? An investigation into public–private sector differences in England. Journal of Health Economics 32, 633–646. URL: https://doi.org/10.1016/j.jhealeco.2013.03.003.

Quah, D., 1993a. Empirical cross-section dynamics in economic growth. European Economic Review 37, 426–434. URL: https://doi.org/10.1016/0014-2921(93)90031-5.

Quah, D., 1993b. Galton's fallacy and tests of the convergence hypothesis. The Scandinavian Journal of Economics 95, 427–443. URL: https://doi.org/10.2307/3440905.

Reif, S., Schubert, S., 2024. Hospital capacity reporting in germany during Covid-19. Journal of Economic Behavior & Organization 228, 106730. URL: https://doi.org/10.1016/j.jebo.2024.106730.

Sen-Crowe, B., Sutherland, M., McKenney, M., Elkbuli, A., 2021. A closer look into global hospital beds capacity and resource shortages during the COVID-19 pandemic. Journal of Surgical Research 260, 56–63. URL: https://doi.org/10.1016/j.jss.2020.11.062.

Summers, R., Heston, A., 1991. The penn world table (mark 5): An expanded set of international comparisons, 1950-1988. The Quarterly Journal of Economics 106, 327–368. URL: https://doi.org/10.2307/2937941.

Suzuki, W., 2021. The Collapse of Health Care: Who is the True Culprit? (in Japanese). Kodansha Ltd., Tokyo, JP.

Takahashi, T., Eguchi, S., Ishikawa, M., 2020. Current status of regional healthcare delivery systems-data collection by prefecture and secondary medical region (8th edition, April 2020) Appendix updated (January 2021) (in Japanese). URL: https://www.jmari.med.or.jp/download/WP443/WP443-appendix.pdf. coronavirus Infections Peak Projected Number of Patients and Various Hospital Beds (by Prefecture) (Updated 08/06/2020) (in Japanese).

Takaku, R., Yokoyama, I., 2022. The financial health of "swing hospitals" during the first covid-19 outbreak. Journal of the Japanese and International Economies 65, 101218. URL: https://doi.org/10.1016/j.jjie.2022.101218.

Supplementary material:

Actual hospital bed utilization by institutional ownership during the COVID-19 Omicron variant epidemic in Japan

Appendix A. Nationwide data results (without layer classification)

Figure A.1 presents the non-parametric distribution of total beds by founding entity nationwide (without using layer classification). The blue line represents publicly owned hospitals, the green line represents non-governmental hospitals, and the red line represents both combined. Although size differences exist even among Regional Medical Care Support Hospitals, no clear differences by founding entity are observed in the national data. Figure A.2 shows the reserved bed ratios for all hospitals by founding entity. From Figure A.2, we can see that non-governmental hospitals have a distribution peak at 5%, while publicly owned hospitals show a peak around 6–7%.

Figure A.3 displays the progression of distributions of COVID-19 inpatients per 100 beds (logarithmic values) in the national data from January 19, 2022, to March 16, 2022. The upper part of the figure represents publicly owned hospitals, while the lower part represents non-governmental hospitals. Since the COVID-19 outbreak began in early 2022, we can confirm the distribution shifting rightward as dates progress to February 2 and February 16. Additionally, by March 16, the distribution shifts leftward, indicating the outbreak was subsiding. Regarding differences by founding entity, except for March 16, publicly owned hospitals consistently show distributions positioned further to the right, indicating higher inpatient numbers per 100 beds.

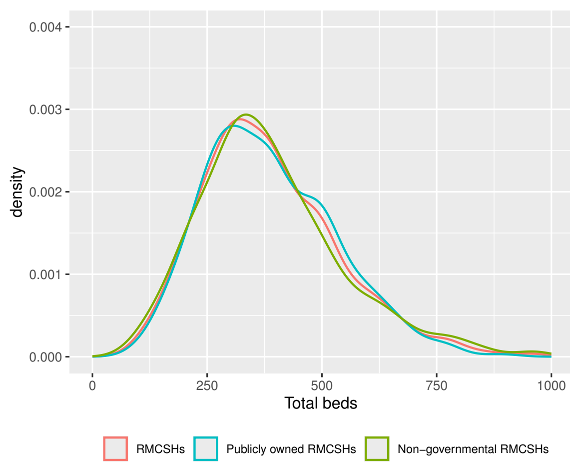

Figure A.1: Distribution of total beds by ownership types

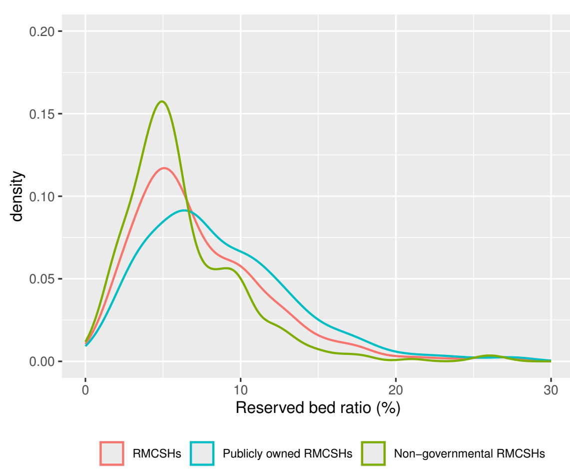

Figure A.2: Distribution of reserved bed ratios by ownership types

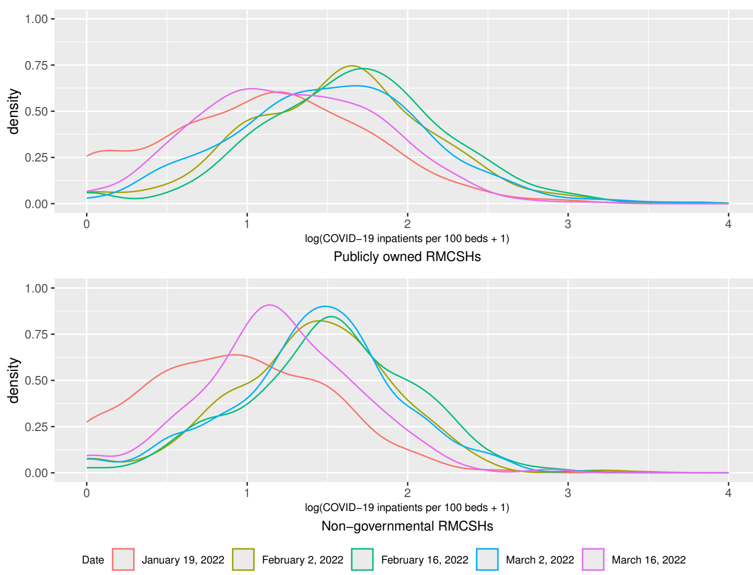

Figure A.3: Trends in inpatients per 100 beds

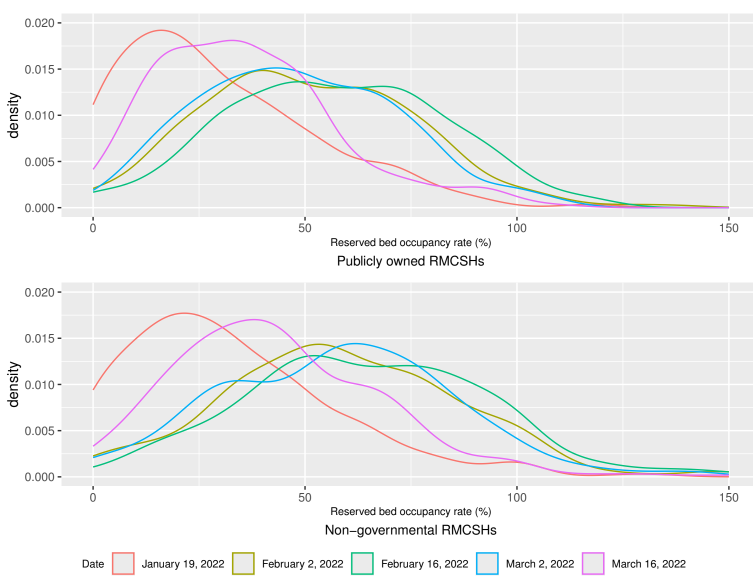

Figure A.4: Trends in reserved bed occupancy rates

Figure A.4 shows the progression of reserved bed occupancy rates in the national data. The distribution of reserved bed occupancy rates on January 19 appears similar between both groups. From February 2 to March 2, when COVID-19 cases increased, and also on March 16, non-governmental hospitals show distributions positioned slightly more to the right. This indicates that while publicly owned hospitals tended to accept more inpatients in absolute numbers, from the perspective of reserved bed occupancy rates, non-governmental hospitals actually showed higher rates. This suggests that although publicly owned hospitals admitted more COVID-19 patients overall, non-governmental hospitals were utilizing a greater percentage of their designated reserved beds.

Appendix B. Results of Layer 2′

As a complement to Layer 2, we present the results from Layer 2′. This consists of hospitals located in secondary medical areas with two or more Regional Medical Care Support Hospitals (RMCSHs), and those in areas with only one such hospital. Similar to Layer 2, Layer 2′ includes prefectural capitals with large populations and major cities. Specifically, RMCSHs are typically core hospitals located in secondary medical areas with an average population of 360,000, but multiple such hospitals may exist in areas with larger populations. These hospitals are expected to handle moderate or severe COVID-19 cases, but if there are two or more RMCSHs within a secondary medical area with different founding entities, there is potential for role division in COVID-19 treatment. If one is a publicly owned hospital and the other is a non-governmental hospital, the former might receive more requests to accept patients, potentially creating differences in their respective roles and utilization patterns.

Table B1 shows the number of hospitals, total beds, and reserved bed ratios by founding entity for hospitals located in secondary medical areas with two or more RMCSHs versus those with only one. Even in prefectural capitals with populations under 1 million, RMCSHs can be concentrated, resulting in only 99 hospitals in secondary medical areas with just one RMCSH, with publicly owned hospitals accounting for 66 (approximately two-thirds) of these. However, in these cases, publicly owned hospitals had smaller bed sizes but higher reserved bed ratios compared to non-governmental hospitals.

Figure B1 shows total beds by founding entity for Layer 2′, Figure B2 shows reserved bed ratios by founding entity, Figures B3 and B4 display COVID-19 inpatients per 100 beds based on whether there are two or more RMCSHs in the secondary medical area, and Figures B5 and B6 show reserved bed occupancy rates based on the same criteria. The general trends observed were similar to those in Layer 2.

Table B.1: Number of hospitals by total beds and ownership types of Layer 2′

Variables	n	Mean	
		Total beds	Reserved bed ratios (%)
Publicly owned RMCSHs in regions with two or more RMCSHs	273	400.392	9.676
Non-governmental RMCSHs in regions with two or more RMCSHs	300	386.933	6.437
Publicly owned RMCSHs in regions with only one RMCSH	66	330.742	9.154
Non-governmental RMCSHs in regions with only one RMCSH	33	410.879	6.157

Note: The variable n is the number of observations.

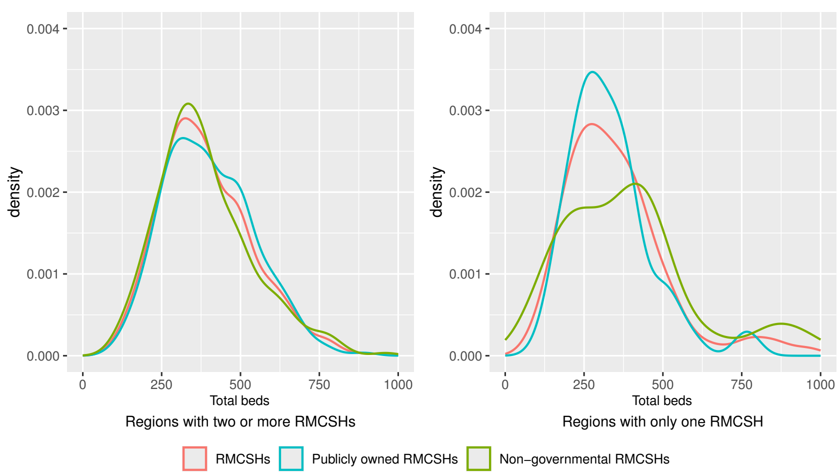

Figure B.1: Distribution of total beds by ownership type at Layer 2′

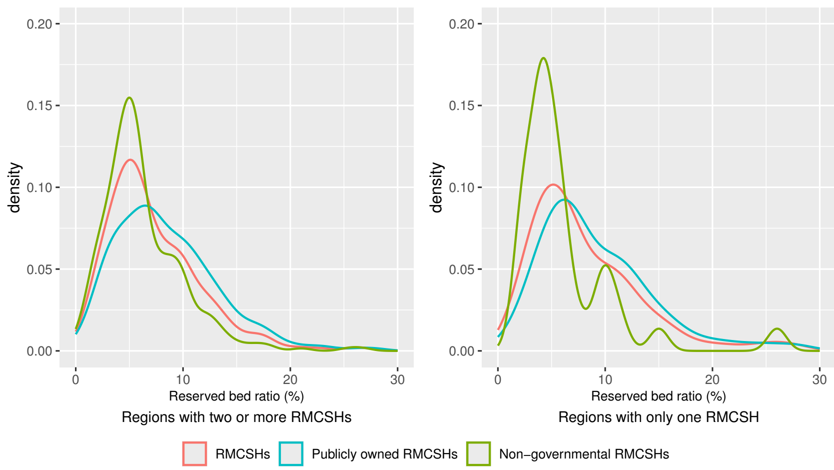

Figure B.2: Distribution of reserved bed ratios (%) by ownership types at Layer 2′

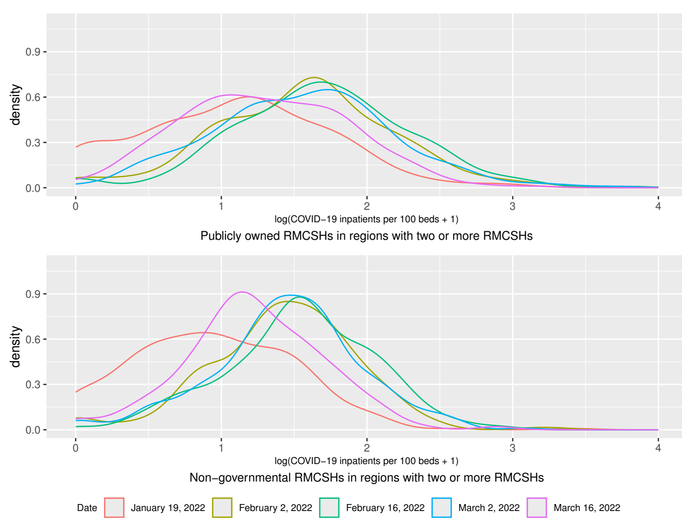

Figure B.3: Trends in the number of inpatients per 100 beds in regions with two or more RMCSHs in Layer 2′

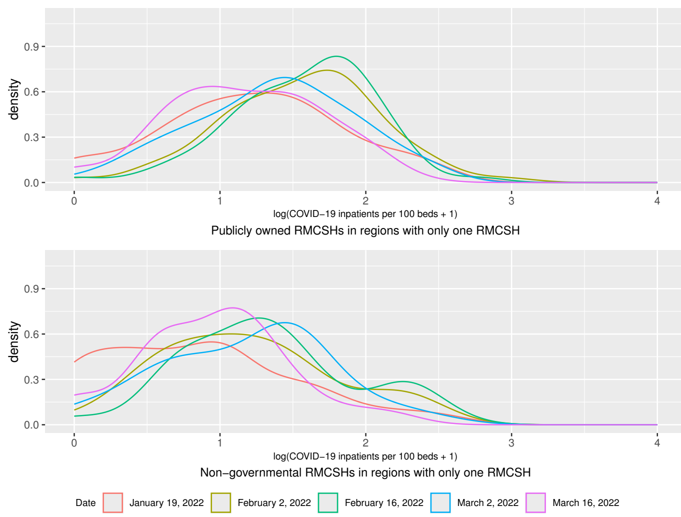

Figure B.4: Trends in the number of inpatients per 100 beds in regions with only one RMCSH in Layer 2′

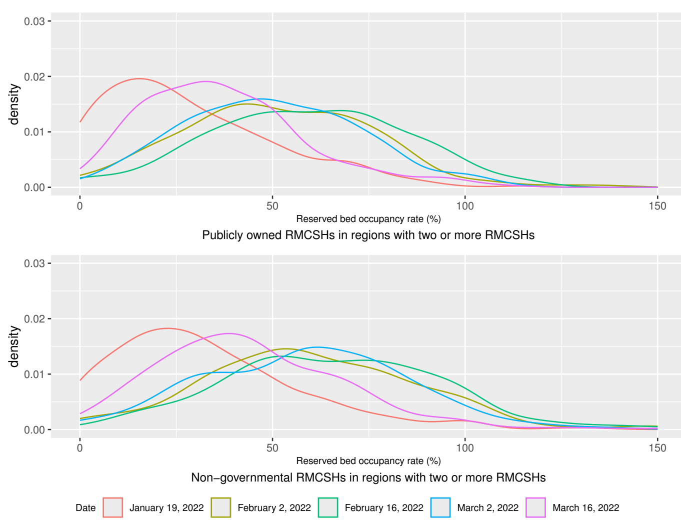

Figure B.5: Trends in reserved bed occupancy rates in regions with two or more RMCSHs in Layer 2′

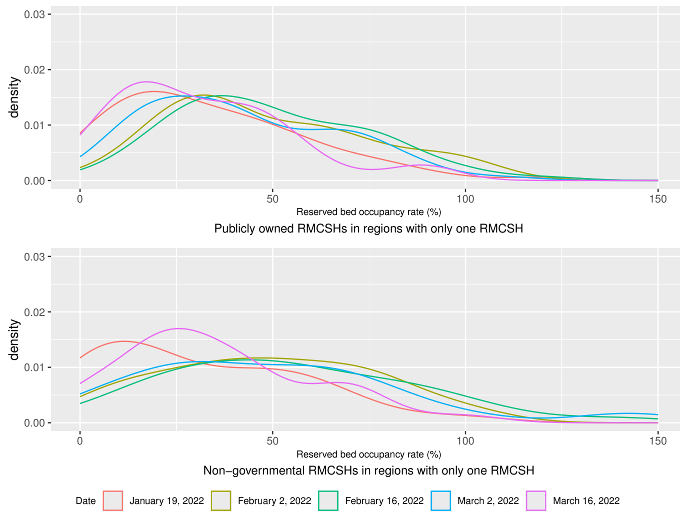

Figure B.6: Trends in reserved bed occupancy rates in regions with only one RMCSH in Layer $2'$

Table C.1: Results of equality tests for total beds by ownership types

Publicly owned RMCSH v.s. Non-governmental RMCSH		p-value	KS's p-value
Without a layer		0.644	0.962
Layer $2'$	With two or more RMCSHs	0.210	0.171
	With only one RMCSH	0.009	0.021

Note: KS stands for Kolmogorov-Smirnov test.

Appendix C. Equality test results of National data and Layer $2'$

Tables C1 through C4 present equivalence tests of distributions by founding entity for the national data and Layer $2'$.

Table C.2: Results of equality tests for reserved bed ratios by ownership types

Publicly owned RMCSH v.s. Non-governmental RMCSH		p-value	KS's p-value
Without a layer		0.000	0.000
Layer $2'$	With two or more RMCSHs	0.000	0.000
	With only one RMCSH	0.001	0.000

Note: KS stands for Kolmogorov-Smirnov test.

Table C.3: Results of equality tests for inpatients per 100 beds by ownership types

Without a layer

Publicly owned RMCSH v.s. Non-governmental RMCSH	p-value	KS's p-value
December 1, 2021	0.113	0.870
January 19, 2022	0.001	0.000
February 2, 2022	0.001	0.000
February 16, 2022	0.009	0.001
March 2, 2022	0.001	0.006
March 16, 2022	0.004	0.038

Layer 2′

Publicly owned RMCSH v.s.	With two or more RMCSHs		With only one RMCSH	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.143	0.951	0.169	0.273
January 19, 2022	0.008	0.010	0.031	0.021
February 2, 2022	0.003	0.006	0.002	0.021
February 16, 2022	0.010	0.008	0.001	0.024
March 2, 2022	0.004	0.008	0.699	0.292
March 16, 2022	0.002	0.042	0.266	0.142

Note: KS stands for Kolmogorov-Smirnov test.

Table C.4: Results of equality tests for reserved bed occupancy rates by ownership types

Without a layer

Publicly owned RMCSH v.s. Non-governmental RMCSH	p-value	KS's p-value
December 1, 2021	0.113	0.870
January 19, 2022	0.001	0.000
February 2, 2022	0.001	0.000
February 16, 2022	0.009	0.001
March 2, 2022	0.001	0.006
March 16, 2022	0.004	0.038

Layer 2′

Publicly owned RMCSH v.s.	With two or more RMCSHs		With only one RMCSH	
Non-governmental RMCSH	p-value	KS's p-value	p-value	KS's p-value
December 1, 2021	0.143	0.951	0.169	0.273
January 19, 2022	0.008	0.010	0.031	0.021
February 2, 2022	0.003	0.006	0.002	0.021
February 16, 2022	0.010	0.008	0.001	0.024
March 2, 2022	0.004	0.008	0.699	0.292
March 16, 2022	0.002	0.042	0.266	0.142

Note: KS stands for Kolmogorov-Smirnov test.

Appendix D. Independence between reserved bed ratios and COVID-19 inpatients per 100 beds

The following section presents contour plots showing the distribution relationship between reserved bed ratios and COVID-19 inpatients per 100 beds, corresponding to Table 9 in our analysis.

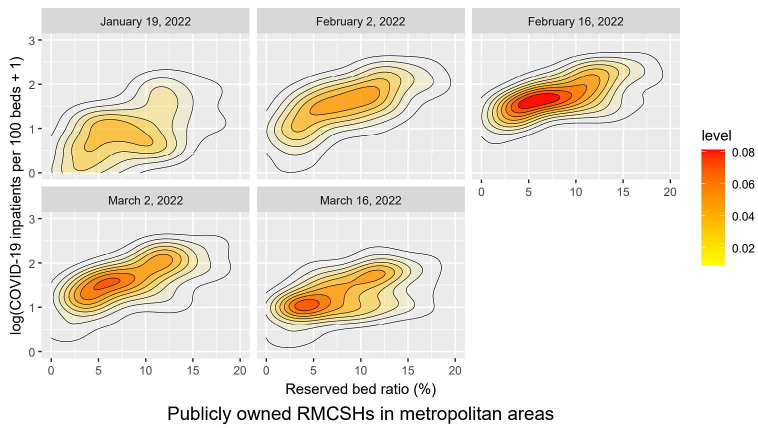

Figure D.1: Publicly owned hospitals in metropolitan areas of Layer 1

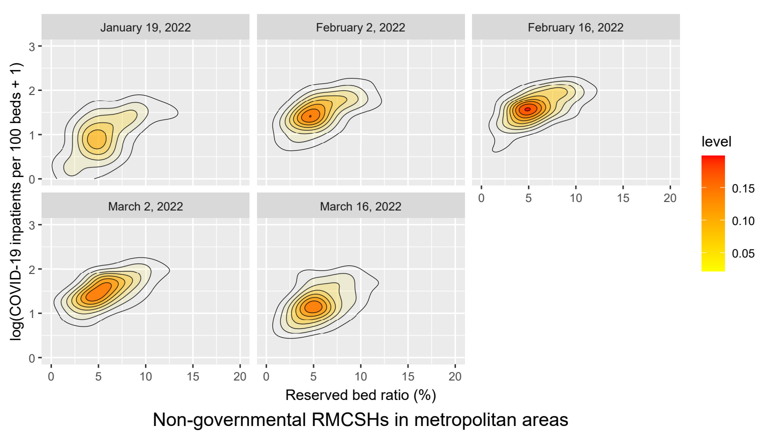

Figure D.2: Non-governmental hospitals in metropolitan areas of Layer 1

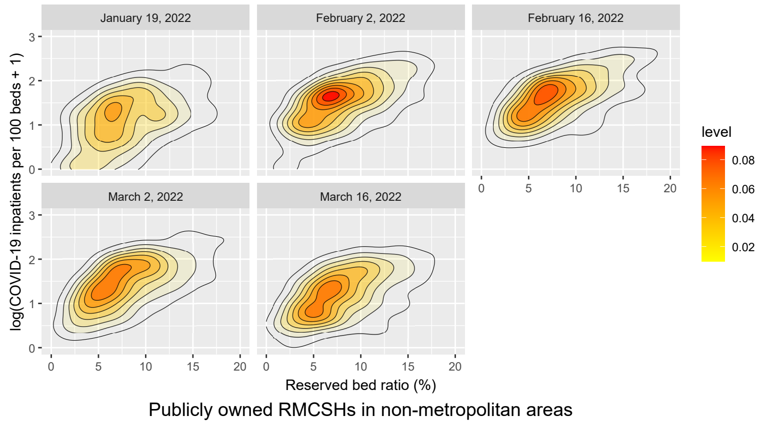

Figure D.3: Publicly owned hospitals in non-metropolitan areas of Layer 1

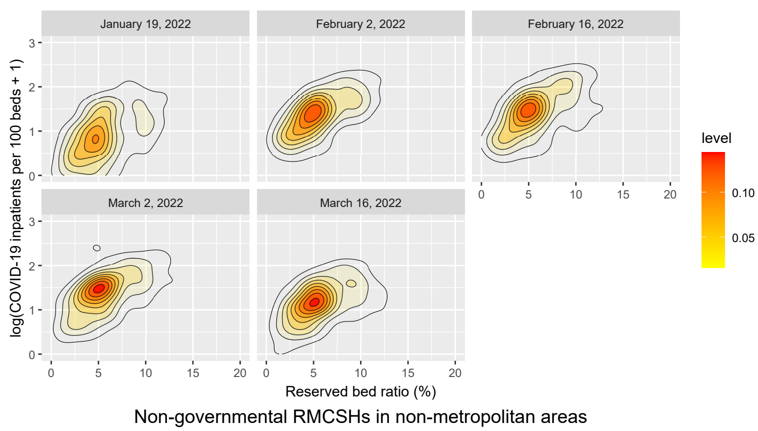

Figure D.4: Non-governmental hospitals in non-metropolitan areas of Layer 1

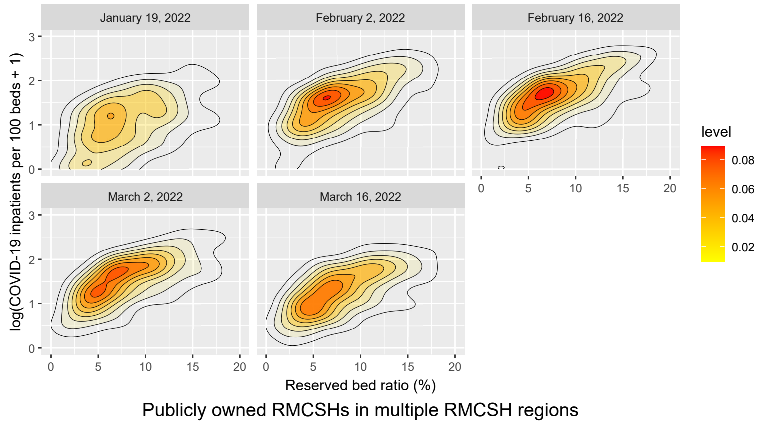

Figure D.5: Publicly owned hospitals in multiple RMCSH regions of Layer 2

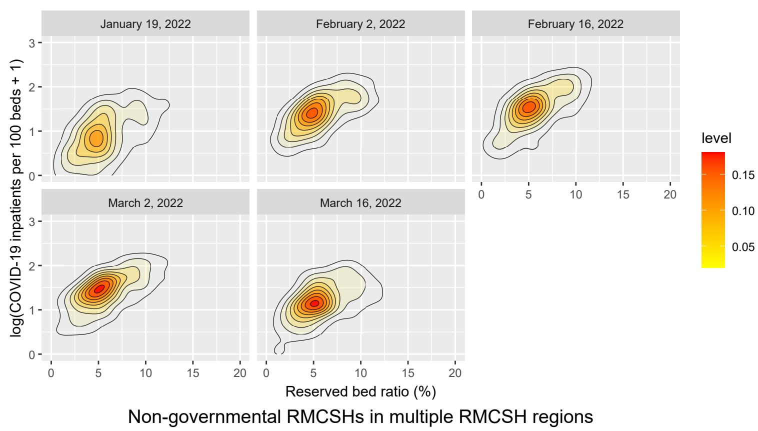

Figure D.6: Non-governmental hospitals in multiple RMCSH regions of Layer 2

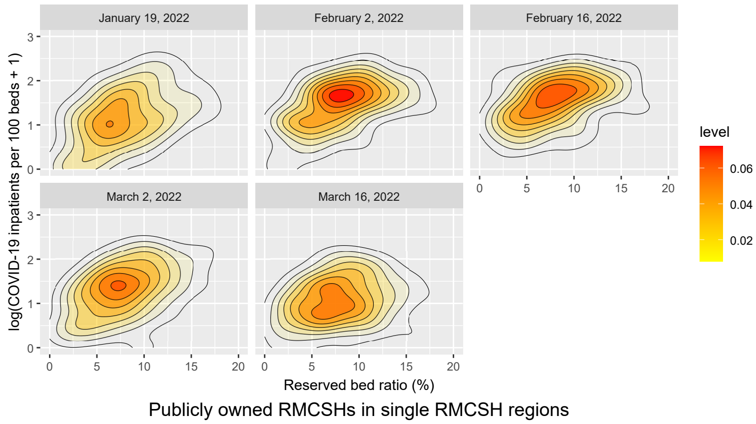

Figure D.7: Publicly owned hospitals in single RMCSH regions of Layer 2

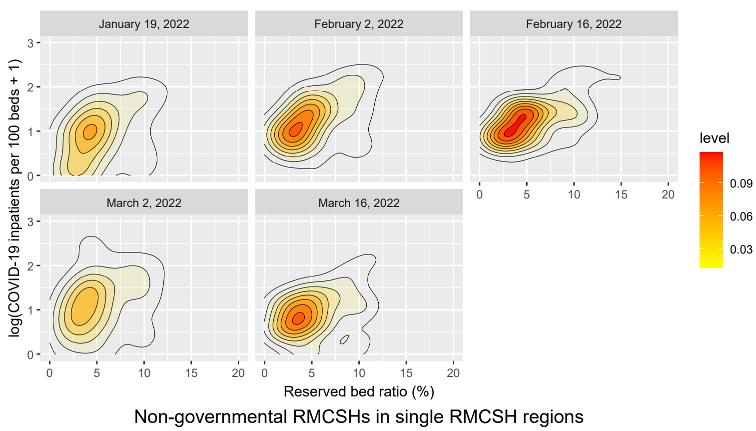

Figure D.8: Non-governmental hospitals in single RMCSH regions of Layer 2

Appendix E. Independence between reserved bed ratios and reserved bed occupancy rates

The following section presents contour plots showing the distribution relationship between reserved bed ratios and reserved bed occupancy rates, corresponding to Table 10 in our analysis.

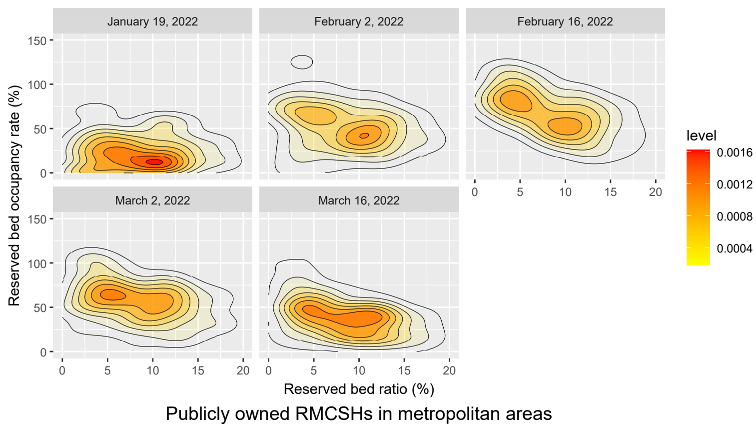

Figure E.1: Publicly owned hospitals in metropolitan areas of Layer 1

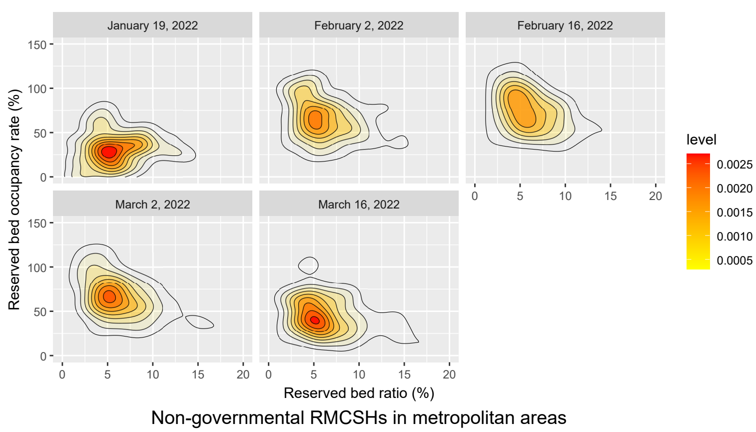

Figure E.2: Non-governmental hospitals in metropolitan areas of Layer 1

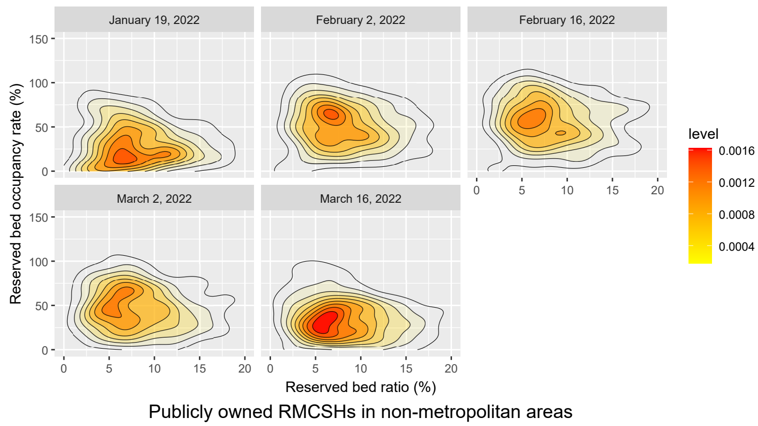

Figure E.3: Publicly owned hospitals in non-metropolitan areas of Layer 1

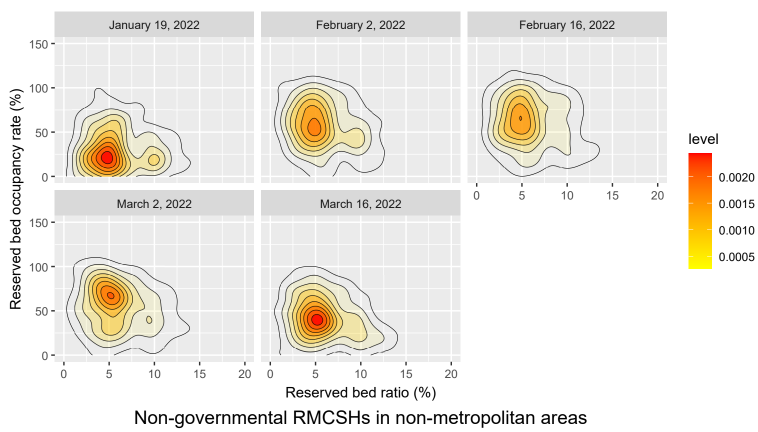

Figure E.4: Non-governmental hospitals in non-metropolitan areas of Layer 1

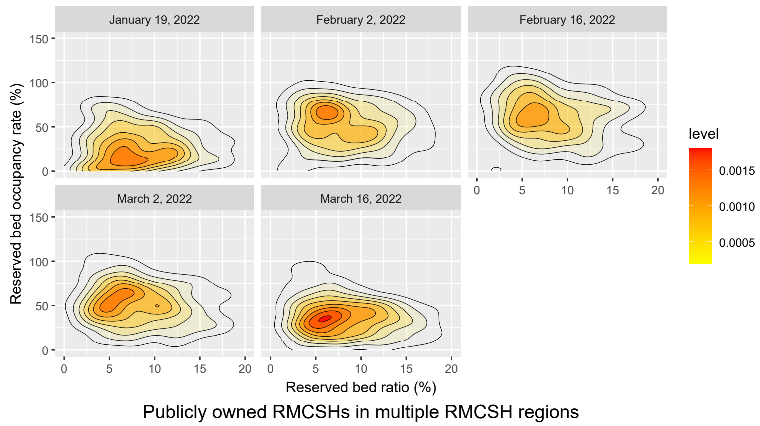

Figure E.5: Publicly owned hospitals in multiple RMCSH regions of Layer 2

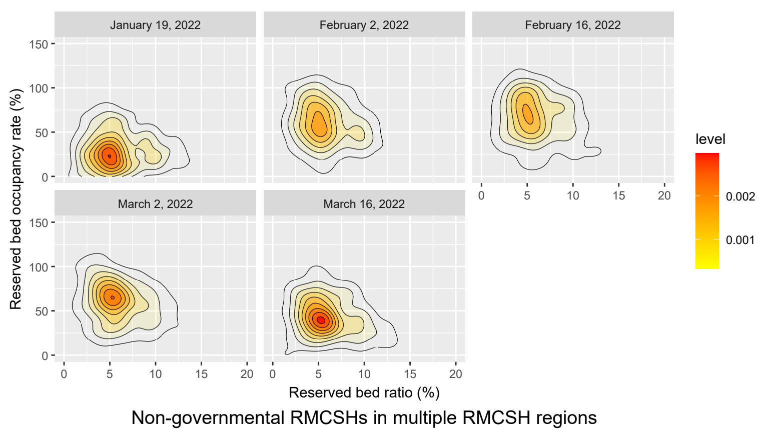

Figure E.6: Non-governmental hospitals in multiple RMCSH regions of Layer 2

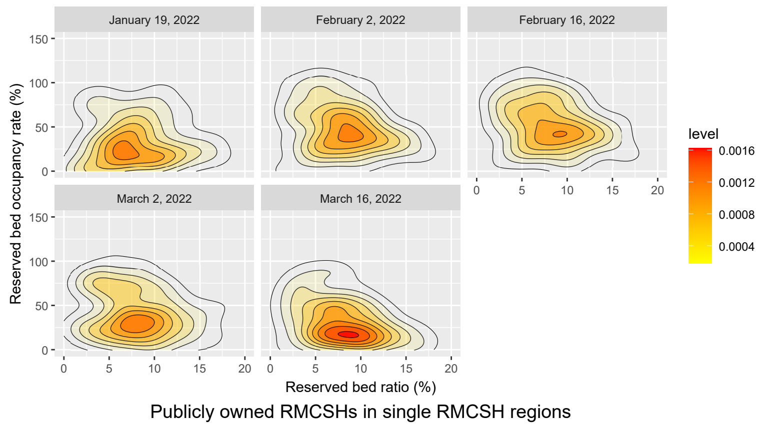

Figure E.7: Publicly owned hospitals in single RMCSH regions of Layer 2

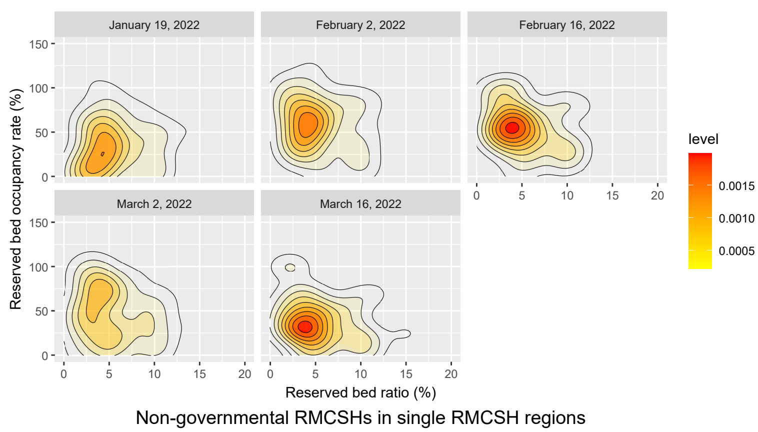

Figure E.8: Non-governmental hospitals in single RMCSH regions of Layer 2