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Analysis of the Forces Driving Public Hospitals' Operating Costs Using LMDI Decomposition: The Case of Japan

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Abstract: The sustainable management of public hospitals is usually threatened by long-term operating deficit, which was exacerbated during the COVID-19 pandemic. This study aimed to quantitatively decompose the historical changes in the annual operating costs of public hospitals in Japan to identify the main driving forces responsible for a worsening imbalance between operating costs and income over the past two decades. A dataset of the annual operating costs of public hospitals in Japan was compiled, in which influencing factors were redefined to make the data amenable to the application of a decomposition method referred to as the Logarithmic Mean Divisia Index (LMDI). Using the LMDI method, the contribution of each influencing factor to the changes in public hospital operating costs was quantitatively determined. The results indicate that, on average, there is an annual reduction in operating costs by JPY 9 million per hospital, arising out of the national reform of public hospitals, but the rapid increase in the prices and worsened structure of costs in recent years resulted in an annual increment of JPY 127 million per hospital to the increasing operating costs. The pandemic revealed damage to the financial balance of public hospitals, but epidemic prevention policies brought an offset to the increased operating cost. A more resilient domestic medical supply chain, the introduction of new technologies, and continuous endeavors in system reform and pricing policies are required to achieve financial sustainability in public hospitals in Japan.

Keywords: factor decomposition; operating costs; hospital management; COVID-19; Japan

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1. Introduction and Background

Public hospitals represent the largest portion of total health spending in most countries, of which socially inclusive and cost-effective healthcare services with lower environmental impact are critical targets for a sustainable healthcare system [1–4]. In most countries with a rapidly increasing ageing population, public hospitals fall into everlasting financial deficit, which makes financial sustainability a core issue [5–7]. The dilemma of whether to simply shut down the low-cost-effective regional hospitals or lower the quality of the healthcare service is always present in a sustainable healthcare system [8]. Meanwhile, temporarily, during pandemic periods such as COVID-19, people falling sick in large numbers has resulted in patients being rushed to public hospitals, immediately causing overcapacity problems, with serious resource and economic costs as a consequence [9–14]. To increase the cost effectiveness of public hospitals, national governments have formulated and implemented various reform plans such as developing a hierarchical medical system, incorporating public hospitals, introducing private capital and more efficient management systems, introducing a prospective payment system, implementing public reporting for price transparency, and even allowing market competition in a bid to suppress operating costs [15–20].

Japan's public hospitals reveal a typical case in challenging the sustainability of healthcare services in an era of ageing and depopulation [21,22]. Since the 1990s, an

increasing number of hospitals have been facing the risks attendant on a continuously worsening financial balance brought about by an inverted population pyramid, making these hospitals vulnerable to bankruptcy in the face of socioeconomic crises or pandemic diseases. From 1996 to the present, the ratio of annual income to operating costs in public hospitals in Japan has always been below 100%; the worst result (83.2%) was recorded during the COVID-19 pandemic (refer to Figure S1 in the Supplementary Document). To reduce the financial deficit ratios, in 2007, the Japanese government formulated a guideline for the institutional reform of public hospitals that emphasized setting numerical targets with the aim of increasing operating efficiency; restructuring and networking public hospitals, including adjusting the numbers of doctors and beds; and resetting the operational status of public hospitals, such as by privatization. Later, a reform plan update of 2015 emphasized the flexible setting of targets to improve operating efficiency, considering the quality of the healthcare service, identifying the role of public hospitals in local healthcare initiatives, adjusting hospital taxation, which takes into account the actual bed occupancy rate, and strengthening financial support to restructure and network public hospitals, among other initiatives [23]. According to statistical reports on the operational status of public hospitals, the annual income/cost ratio jumped to above 92% from 2008 and remained stable for 4 years after the introduction of the 2007 reform plan, but fell again even after the implementation of the reform plan update of 2015.

The forces that drive increases in operating costs of public hospitals faster than their incomes, and the means by which these driving forces can be controlled to realize the status of financial sustainability, need to be understood and methods for evaluating the institutional reform policies mentioned above need to be devised. Direct statistical data can only represent the total cost increases, including salaries, materials, medicines, depreciation, and other costs (research and training costs, commission fees, and the others) [24] (refer to Figure S2 in the Supplementary Document), and fail to explain how the internal and external factors influence the changes in operating costs. Without the application of quantitative analysis to identify the driving forces, it is difficult for the government and hospitals to formulate specific action plans to counter the expanding financial deficit.

Worldwide, various analytical tools such as data envelope analysis, regression models, and time series analysis have been applied to evaluate the improvements in efficiency at public hospitals after institutional reform and to identify the key influencing factors that significantly affect the operating effectiveness of these institutions [6,17,25–27]. However, regarding the application of these analysis tools, previous case studies in Japan had not reached definitive conclusions on what the key forces driving the public hospitals' operating costs are. Some of them identified salary costs, material costs, and the number of outpatients as the main factors [28] (risk factor analysis) [29] (regression analysis) [30] (cluster analysis), while some of them denied this result [31] (regression analysis). Among tens of indicators, many are mentioned as key factors, such as inpatient unit price, average daily number of inpatients, and outpatient unit price [32] (regression analysis), and outpatient number and inpatient unit price [33] (regression analysis). Geographically, factors such as the number of persons per household, the unemployment rate, and the ratio of the elderly in the population were also mentioned as key factors [34]. In conclusion, the results are inconsistent because of different perspectives and research designs regarding variable selection, while the approaches have been unable to track the impacts from historical events and quantitatively evaluate the contribution from driving forces.

Beyond the analysis tools mentioned above, decomposition methods, such as the Logarithmic Mean Divisia Index (LMDI), make it possible to extract the driving forces from various internal and external factors to an aggregate indicator [35]. Since the LMDI method can be used to completely decompose the changes in an overall indicator to the contributions of influencing factors, it has become a commonly used decomposition method that is often applied to analyses of the driving forces behind carbon emissions [36–39] and energy consumption [40–42] of a city, region, country, or sector [42–44]. The LMDI method is also applied to decomposition studies in other fields, but this method had

never formerly been used for analyzing changes in the overall financial performance of a hospital. Compared to regression analysis, the LMDI method may mask some of the complex interactions between influencing factors, but can immediately reveal the structural changes between influencing factors before and after institutional reform, even those that occurred during the COVID-19 pandemic.

This study aimed to quantitatively decompose the historical changes in the annual operating costs of public hospitals in Japan to identify the main forces responsible for driving the worsening imbalance between operating costs and income over the preceding two decades. This will not only provide further evidence that can be used in the evaluation of the effectiveness of the recent institutional reforms of the public healthcare system, but will also provide an overarching perspective of the impacts arising from the socio-economic changes to the operation of public hospitals that will in turn support further policy making. In addition, as this is the first time the LMDI method has been applied to the field of healthcare, this study will also provide a reference for the academic community to broaden the scope of research in this area.

The rest of this paper is organized as follows: Section 2 describes model development and the process of data collection, Section 3 summarizes the decomposition results on operation costs of public hospitals, along with some discussion, and Section 4 presents the main findings from the study and their policy implications.

2. Materials and Methods

2.1. Theoretical Analysis and Indicator Selection

LMDI is one of the many specific decomposition methods developed based on Index Decomposition Analysis, which is an analytical tool that originated from energy studies [45]. Although many other options such as Laspeyres and Divisia can also be applied, they do not deal with residuals that lead to large error estimation [46]. In contrast, LMDI can fully decompose the residual. Conventionally, an aggregate indicator can be decomposed into at least 3 factors, namely the overall activity (activity effect), activity mix (structure effect), and sectoral intensity (intensity effect). This study followed an analytical design that considered population, income, and consultation rate to represent the overall activity, while the coverage of public hospitals in terms of the total consultation, visit duration of a single consultation, and the structure of operating costs represent the activity mix and sectoral intensity. The definitions of these 6 factors are summarized in Table 1.

Table 1. The aggregate and influencing factors defined in this study.

Factor	Definition
C^t	Average total operating costs of one public hospital in Japan in year t (JPY)
Pop^t	Population of Japan in year t (person)
In^t	Annual income per capita in year t (JPY/person) (income level)
N^t	Consultation rate by annual income in the year t (times/JPY) (health level)
R^t	Coverage of one public hospital in terms of total annual medical consultations in year t (%) (service scope)
T^t	Visit duration for a single consultation to a public hospital, including inpatients and outpatients, in year t (days/visit); here, a single consultation of an outpatient is counted as a one-day stay in a public hospital (length of stay)
Cs_i^t	Type i operating cost for one patient during his/her one-day stay in a public hospital in year t (JPY/day) (structure of operating costs)

Accordingly, the operating costs of one public hospital can be aggregated as the product of these factors, using the following Equation (1):

$$C^t = \sum_i C_i^t = \sum_i Pop^t \times In^t \times N^t \times R_i^t \times T^t \times Cs_i^t \quad (1)$$

Here, population is a kind of total indicator, while average income, consultation rate, and visit duration for a single consultation are the factors influencing the level of demand for medical consultations; the coverage of public hospitals for medical consultations means the service scale of public hospitals, and each term of the operating cost points to the management

costs of public hospitals in providing medical consultations for the public. As hypotheses in this study, these factors are likely to be affected by several historical events, as follows:

- The ageing rate in Japan was over 20% in the year 2005, while the population began to decline from 2010 [47].
- The subprime mortgage crisis of 2008 led to a temporary decrease in personal income in Japan [48].
- In 2013, the Bank of Japan introduced a quantitative−qualitative easing policy that aimed to achieve a target inflation rate of 2%, which continues to the present, but in fact this has led to a long-term devaluation of the Japanese Yen currency [49,50].
- The 2007 guideline for the institutional reform of public hospitals and the following updated 2015 reform plan established by the Japanese government had long-term comprehensive impacts on the number and scale, costs management, income system, and the consultation rate of public hospitals [32].
- The COVID-19 pandemic has shocked the whole healthcare system, from 2020 to the present [51].

In this study, the definitions of operating costs of public hospitals as defined in the Yearbook of Local Public Enterprises [24] were followed, which includes salaries, materials, medicines, depreciation, and other costs (research and training costs, commission fees, etc.), but excludes interest costs, extraordinary losses, and other non-operating costs.

2.2. Data Preparation

To apply LMDI decomposition to the operating costs, some of the necessary data could be obtained from statistics reports, while the other data were estimated based on reliable statistics from other sources. In this study, the population and income data were obtained from the national annual statistics of Japan, while the overall indicators, such as consultation times of inpatients and outpatients, were obtained from the Survey of Medical Institutions issued by the Ministry of Health, Labour and Welfare [52], and the data on public hospitals were obtained from the Yearbook of Local Public Enterprises published by the Ministry of Internal Affairs and Communications [24]. As summarized in Table 2, the data of influencing factors defined in this study were prepared from the relevant statistical data.

Table 2. Data preparation for LMDI decomposition from the corresponding statistical report.

Factor	Variable Definition	Formula
Population	Population	①
Personal income level	Annual income per capita	③/①
Personal health level	Consultation rate by annual income	$\frac{(⑧+⑨/⑩)/③}{(④+⑤)/(⑥+⑦)}$
Service scope of public hospitals	Coverage of one public hospital in terms of yearly medical consultations	$\frac{④+⑤}{⑥+⑦}/②$
Length of stay in public hospitals	Visit duration for a single consultation at a public hospital, including inpatients and outpatients	$\frac{⑧+⑨}{⑧+⑨/⑩}$
Structure of operating costs of public hospitals	Material costs for one patient during his/her one-day stay in a public hospital	⑪/(⑧ + ⑨)
	Medicine costs for one patient during his/her one-day stay in a public hospital	⑫/(⑧ + ⑨)
	Salary costs for one patient during his/her one-day stay in a public hospital	⑬/(⑧ + ⑨)
	Depreciation costs for one patient during his/her one-day stay in a public hospital	⑭/(⑧ + ⑨)
	Other costs for one patient during his/her one-day stay in a public hospital	⑮/(⑧ + ⑨)

Notes: Primary data from the statistics and reports: ① population, from [53], ② number of public hospitals, ④ number of outpatients per day in public hospitals, ⑤ number of inpatients per day in public hospitals, ⑧ annual gross number of outpatients in public hospitals, ⑨ annual gross number of inpatients in public hospitals, ⑪ material costs, ⑫ medicine costs, ⑬ salary costs, ⑭ depreciation costs, ⑮ other costs, from [24]. ③ Annual income, from [48]. ⑥ Number of outpatients per day in all hospitals, ⑦ number of inpatients per day in all hospitals, ⑩ average visit duration of inpatients in all hospitals, from [52].

Accordingly, the values of influencing factors were obtained and readied for LMDI decomposition, as shown in Table 3.

Table 3. Historical changes in factors influencing the operating costs of a public hospital.

Based on One Public Hospital	Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Population	million	125.9	126.2	126.5	126.7	126.9	127.3	127.5	127.7	127.8	127.8	127.9	128.0	128.1	128.0	128.1	127.8	127.6	127.4	127.2	127.1	127.0	126.9	126.7	126.6	126.1	125.5
Annual income per capita	million JPY/capita	3.37	3.35	3.27	3.25	3.34	3.22	3.19	3.24	3.30	3.31	3.35	3.35	3.10	3.00	3.09	3.05	3.06	3.18	3.25	3.41	3.40	3.48	3.50	3.50	3.32	3.51
Consultation rate by annual income	patient-times/million JPY	1.43	1.42	1.45	1.45	1.42	1.47	1.43	1.37	1.31	1.29	1.24	1.20	1.25	1.28	1.24	1.24	1.24	1.18	1.15	1.09	1.08	1.06	1.05	1.03	1.01	0.98
Coverage of one public hospital in terms of yearly medical consultations	%	0.023	0.023	0.024	0.024	0.024	0.024	0.023	0.023	0.023	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
Visit duration for a single consultation at a public hospital, including inpatients and outpatients	days/visit	1.50	1.50	1.49	1.49	1.49	1.48	1.51	1.53	1.54	1.55	1.56	1.56	1.57	1.57	1.58	1.58	1.57	1.57	1.57	1.57	1.57	1.58	1.58	1.58	1.58	1.55
Material costs for one patient during his/her one-day stay in a public hospital	JPY/patient-day	1759	1808	1870	1926	1940	1981	2132	2247	2293	2426	2449	2420	2527	2603	2529	2583	2617	2756	2785	2874	2907	3040	3096	3190	3476	3712
Medicine costs for one patient during his/her one-day stay in a public hospital	JPY/patient-day	3642	3528	3388	3250	3047	2889	2882	2751	2688	2744	2746	2827	2806	2831	2845	2919	2939	3024	3030	3315	3318	3381	3522	3829	4122	4139
Salary costs for one patient during his/her one-day stay in a public hospital	JPY/patient-day	8912	9254	9409	9436	9416	9479	9844	10,021	10,253	10,559	10,956	11,451	11,992	12,326	12,432	12,769	13,081	13,335	13,859	14,304	14,941	15,250	15,637	16,096	18,981	18,693
Depreciation costs for one patient during his/her one-day stay in a public hospital	JPY/patient-day	955	1007	1078	1168	1180	1195	1272	1363	1401	1473	1560	1648	1734	1739	1735	1751	1785	1869	2284	2368	2468	2517	2571	2603	2894	2790
Other costs for one patient during his/her one-day stay in a public hospital	JPY/patient-day	2642	2757	2838	2928	3053	3175	3409	3646	3906	4190	4522	5027	5397	5529	5729	5809	5964	6275	6367	6434	6484	6658	6815	7057	7262	7173

2.3. Decomposition by LMDI Method

In this study, the calculation process described in the practical guideline for applying the LMDI method provided by Ang [54] was followed. According to the definitions of the aggregate indicator and influencing factors mentioned above, the annual changes in the indicator (operating cost) can be calculated as the sum of the contribution of each influencing factor (Table 4), as in the following Equation (2):

$$\Delta C = \Delta C_{Pop} + \Delta C_{In} + \Delta C_N + \Delta C_R + \Delta C_T + \Delta C_{Cs} \quad (2)$$

Table 4. The contribution from each influencing factor to the total operating cost.

Variable	Definition
ΔC	Annual changes in total operating cost of one public hospital (JPY)
ΔC_{Pop}	Annual contribution from population changes in Japan to the operating cost of one public hospital (JPY)
ΔC_{In}	Annual contribution from income level changes to the operating cost of one public hospital (JPY)
ΔC_N	Annual contribution from consultation rate changes to the operating cost of one public hospital (JPY)
ΔC_T	Annual contribution from the changes in patient visit duration to the operating cost of one public hospital (JPY)
ΔC_{Cs}	Annual contribution from the structural changes and cost-efficiency management level to the operating cost of one public hospital (JPY)

Next, the annual contribution of each influencing factor can be calculated using the following Equations (3)–(8):

$$\Delta C_{Pop} = \sum_i \Delta C_{Pop,i} = \begin{cases} \Delta C_{Pop,i} = 0, \text{ if } Pop_i^t \times Pop_i^0 = 0 \\ \Delta C_{Pop,i} = \sum_i L(C_i^t, C_i^0) \ln\left(\dfrac{Pop_i^t}{Pop_i^0}\right) \\ \text{, if } Pop_i^t \times Pop_i^0 \neq 0 \end{cases} \quad (3)$$

$$\Delta C_{In} = \sum_i \Delta C_{In,i} = \begin{cases} \Delta C_{In,i} = 0, \text{ if } In_i^t \times In_i^0 = 0 \\ \Delta C_{In,i} = \sum_i L(C_i^t, C_i^0) \ln\left(\dfrac{In_i^t}{In_i^0}\right) \\ \text{, if } In_i^t \times In_i^0 \neq 0 \end{cases} \quad (4)$$

$$\Delta C_N = \sum_i \Delta C_{N,i} = \begin{cases} \Delta C_{N,i} = 0, \text{ if } N_i^t \times N_i^0 = 0 \\ \Delta C_{N,i} = \sum_i L(C_i^t, C_i^0) \ln\left(\dfrac{N_i^t}{N_i^0}\right) \\ \text{, if } N_i^t \times N_i^0 \neq 0 \end{cases} \quad (5)$$

$$\Delta C_R = \sum_i \Delta C_{R,i} = \begin{cases} \Delta C_{R,i} = 0, \text{ if } R_i^t \times R_i^0 = 0 \\ \Delta C_{R,i} = \sum_i L(C_i^t, C_i^0) \ln\left(\dfrac{R_i^t}{R_i^0}\right) \\ \text{, if } R_i^t \times R_i^0 \neq 0 \end{cases} \quad (6)$$

$$\Delta C_T = \sum_i \Delta C_{T,i} = \begin{cases} \Delta C_{T,i} = 0, \text{ if } T_i^t \times T_i^0 = 0 \\ \Delta C_{T,i} = \sum_i L(C_i^t, C_i^0) \ln\left(\dfrac{T_i^t}{T_i^0}\right) \\ \text{, if } T_i^t \times T_i^0 \neq 0 \end{cases} \quad (7)$$

$$\Delta C_{Cs} = \sum_i \Delta C_{Cs,i} = \begin{cases} \Delta C_{Cs,i} = 0, \text{ if } Cs_i^t \times Cs_i^0 = 0 \\ \Delta C_{Cs,i} = \sum_i L\left(C_i^t, C_i^0\right) \ln\left(\dfrac{Cs_i^t}{Cs_i^0}\right) \\ \text{, if } Cs_i^t \times Cs_i^0 \neq 0 \end{cases} \quad (8)$$

where $L(a,b) = (a-b)/(\mathrm{In}a - \mathrm{In}b)$.

3. Results

3.1. Historical Changes in Influencing Factors

As seen in Table 3, first, it is clear that the population of Japan continued to increase, reaching 128.1 million by 2010, but then began to decrease from that point onward. In contrast, annual income per capita showed an overall decreasing trend up until 2009, but then began to increase after that. Second, the consultation rate by annual income per capita revealed an amazing 32% decrease from 1996 to 2021, while the coverage of one public hospital as a proportion of total medical consultations peaked in 2000 and then began to decrease to some extent. Third, the visit duration for a single medical consultation to a public hospital revealed a continuous increase from 2000. From these factors, after 2000, the public hospital system was also found to have become more concentrated on a regional scale and also became more effective in the area of critical medical care compared to other hospitals. However, the various costs per one patient during his/her one-day stay in a public hospital showed a continuous increase in recent years; in particular, the salary costs doubled during the period from 1996 to 2021. Although the depreciation costs and other costs were not the largest contributors to the total operating cost, the rate of increase remained the same as that for salary costs. Interestingly, only the medicine costs initially kept decreasing until 2009, and then began to increase, until finally reaching the same level in 2019 that they were in 1996.

3.2. Contribution of Influencing Factors Based on Decomposition Results

The decomposition results for the annual contribution of influencing factors are summarized in Figure 1. In general, the net changes in operating cost at one public hospital consistently showed an increasing trend from 1996, but the increase declined during the period from 1996 to 2006, and then suddenly increased again from then onward. From the decomposition of each influencing factor, it is obvious that the costs for a patient during a stay in hospital made the greatest contribution to the increase in the total operating cost of one public hospital. This contribution included two types of effects: one was from the overall increase in each branch of operating cost, and the other was because of a worsening cost structure in which the branch with the larger proportion of the total (salary cost) increased faster than the other branches with smaller proportions. Annually, the rising cost contributed around JPY 45 million to the total operating cost.

In contrast, the contribution from the changing consultation rate by annual income generally remained negative, and it fell annually by around JPY 30 million as a proportion of the total operating cost. However, this reduction was largely offset by the contribution from the changes in annual income per capita. During the entire period, visit duration for a single consultation continued to contribute around JPY 10 million annually to the total operating cost. Additionally, the coverage of one public hospital as a proportion of total yearly medical consultations contributed to some reduction in total operating cost before 2010, but stopped after that. The smallest contribution came from the changing population in Japan, so this contribution can be ignored in the short- and medium-term analysis. Notably, the COVID-19 pandemic, beginning from the year 2020, caused a significant shock to the financial balances of public hospitals, where the average cost for treating a patient immediately shot up, but this increase was substantially offset. Comparing the contributions among all influencing factors, it can be concluded that the increasing cost levels and worsening cost structure were the main forces driving the long-term increase in

total operating cost in a public hospital, while the other influencing factors were almost all yearly variables that affected the total operating cost in a single fiscal year.

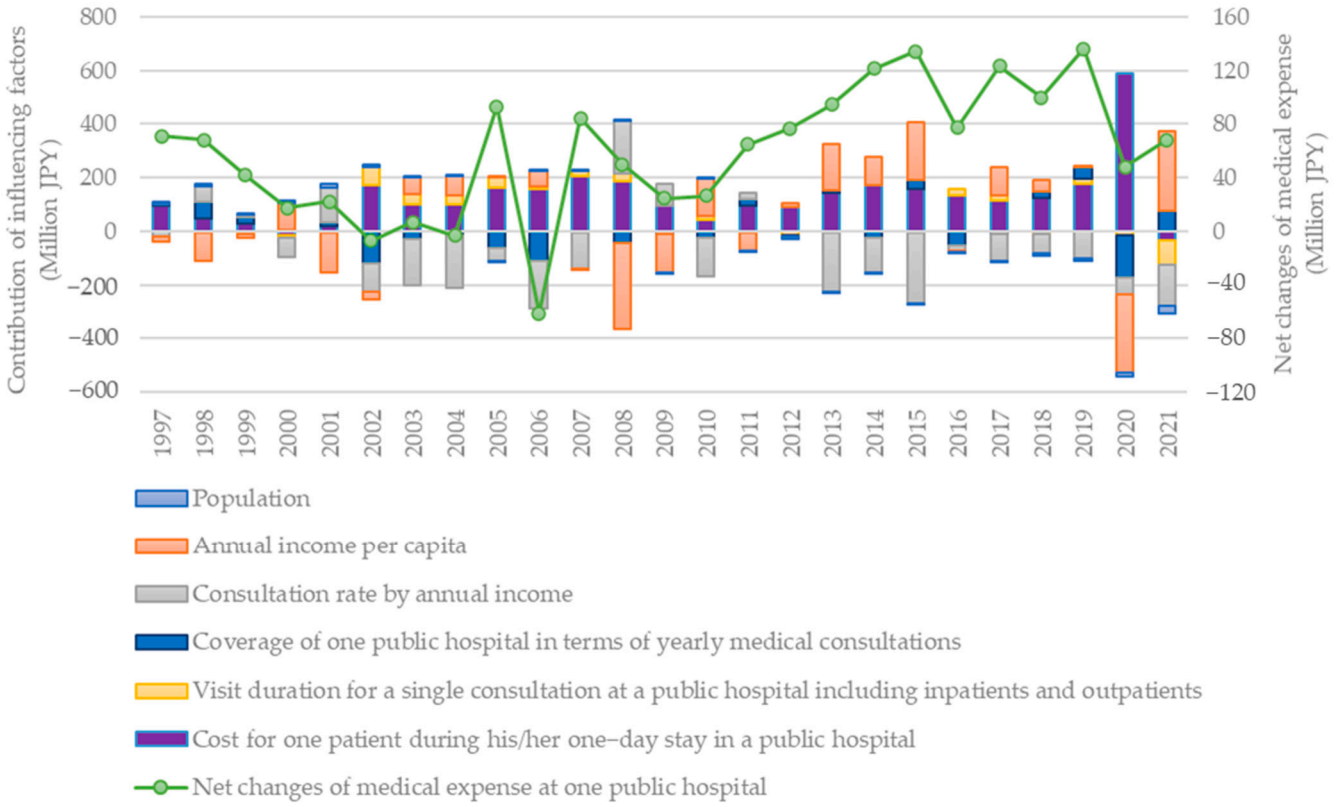


Figure 1. Decomposition results of various factors influencing the total operating cost in a public hospital.

3.3. Facts beyond the Decomposition Results

3.3.1. Impact from the Institutional Integration of Public Hospitals

A broad institutional reconfiguration of public hospitals in Japan arose out of the national systemic reform of public hospitals in 2007. As shown in Figure 2, the number of public hospitals in Japan rapidly decreased during the decades, from 1000 hospitals at the peak to 753 at the end of the study period. Many of the hospitals were disestablished, incorporated, restructured, or assigned to private owners [24]. In particular, the institutional reform of public hospitals of 2007 redefined the importance of public hospitals to support regional medical systems in cooperation with private hospitals and clinics. Public hospitals with serious human resource shortages were downgraded to regional clinics, while some others with financial problems were transferred into local incorporated administrative agencies, which enabled them to source their own funds to allow ongoing operation [55]. An improved hierarchical medical system not only reduced the consultation rate to public hospitals because they were more focused on treating critical patients [56], but also reduced the coverage of one public hospital as a proportion of total yearly medical consultations because of the integration [57]. As shown in Table 3, one public hospital used to perform on an annual basis 0.024% of the total number of medical consultations for all hospitals in 2000, but the coverage began to decrease during the period of institutional reform of public hospitals. Furthermore, it also brought about a continuous increase in the charge income level by 87.6% during 1996–2021, which is a positive outcome, and evidence shows the success of the institutional reforms [24]. However, such activities conversely led to a continuous increase in the visit duration for a single consultation and the operating cost for one patient per one-day stay, which substantially offset the positive effects mentioned above.

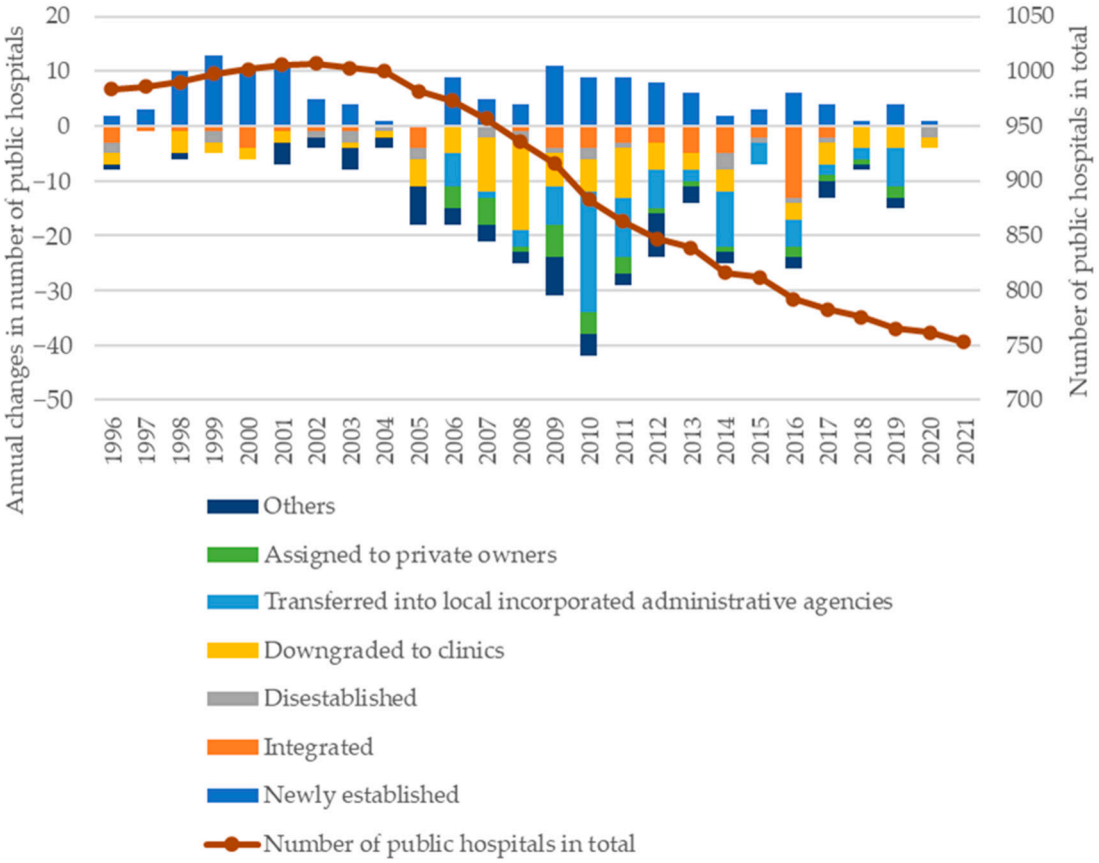


Figure 2. Changes in the number of public hospitals in Japan (details of the change in 2021 were not recorded in the statistics at the time of this study).

3.3.2. Operating Cost Level Changes Compared with Charge Income Level

Next, the question as to whether the institutional integration of public hospitals failed in controlling the operating cost level was addressed. One simple test is to compare the change rate of charge income to that of operating costs. As can be seen from Figure 3, the changes in charge income level are closely correlated with the increases in salary costs. According to the statistics, the number of staff remained at 220,000 in the past, and the patient number per staff gradually decreased, but the average annual salary increased from JPY 8.33 to 9.24 million [24,56]. In addition, material costs, depreciation costs, and other incidental costs also generally followed the same path of annual changes as charge income. The only mismatch was with the medicine costs, which apparently increased more slowly than the charge income level before 2010, but gradually increased more rapidly than the latter from that point onward. In fact, the consumer price index was always around 95% during 1996–2013, and then slightly recovered to 100% afterwards as a result of monetary easing policy [58]. By contrast, the exchange rate of USD to JPY increased from approximately 80 to 120 during 2011–2021 [59]. Accordingly, the changes in unit material and medicine costs matched with the trend of JPY exchange rate very well. The medicine prices seemed to play an external role by affecting changes in the total operating cost of Japan's public hospitals. It is not clear why the depreciation costs suddenly increased in year 2014, but generally they were prevented from contributing to the increase in total operating cost.

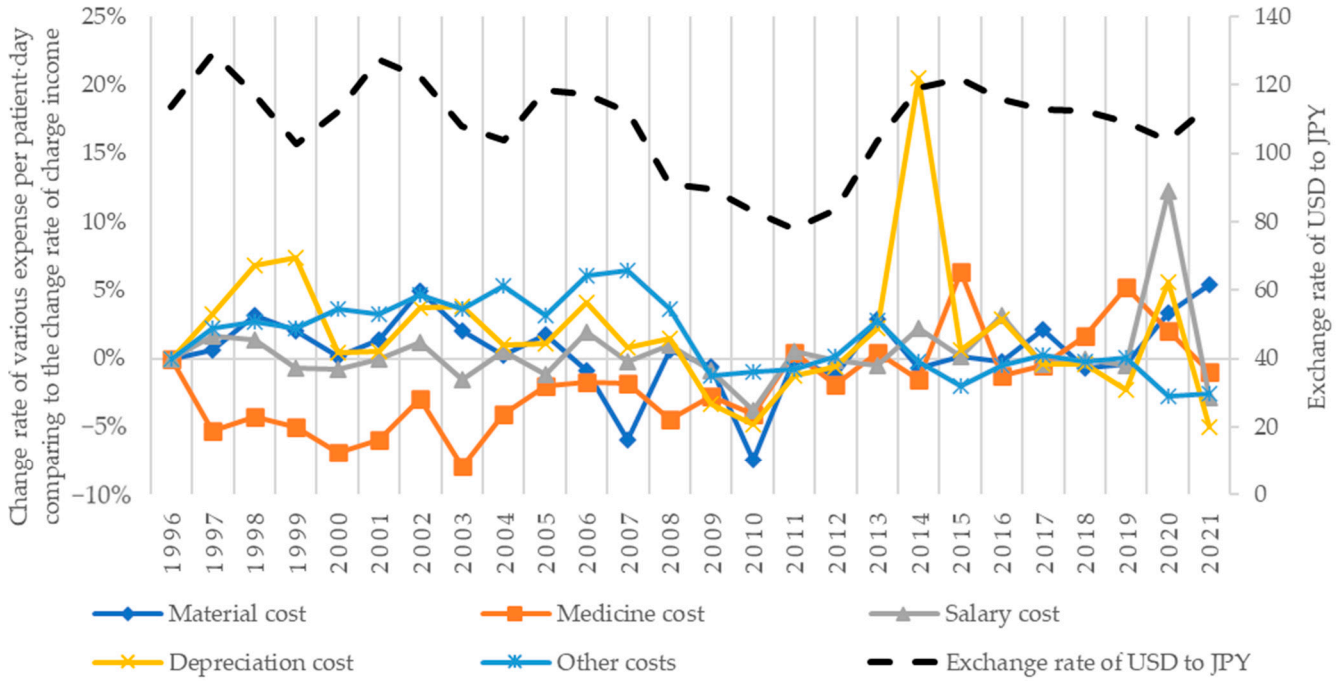


Figure 3. Relative change rate of various costs for a patient during a one-day stay in a public hospital against the change rate of charge income.

3.3.3. Impacts from the COVID-19 Pandemic

As shown in Figures 1 and 3, the COVID-19 pandemic caused a great shock to the cost structure of public hospitals, but the overall impacts on operating costs were limited. In the year 2020, salary costs suddenly increased because of the serious shortage of medical staff, which contributed substantially to the increase in operating costs. However, the consultation rate and the coverage of one public hospital in terms of yearly medical consultations recorded the lowest rate, because public hospitals became locations of cluster infection and many patients tried to avoid visiting them, or could not visit public hospitals due to city-wide lockdowns and temporary regulations for public hospitals [60]. The decline in annual income caused by unemployment also greatly offset the increase in operating costs. In the next year, 2021, although annual income recovered and patients returning to public hospitals contributed to an increase in operating costs, this increase was offset by the suppressed salary costs and reduced consultation rates and visit durations, when medical staff returned and the patients strengthened their self-protection from nosocomial infection [61]. During the pandemic, material and medicine costs continuously increased because of the serious price increases in Japan caused by the devaluation of the JPY and worldwide inflation. According to the Trade Statistics of Japan issued by the Ministry of Finance, Japan's importation of medical materials and medicines had surpassed exports for decades, particularly after the COVID-19 pandemic [47]. In 2021, the value of Japan's imported medicines reached USD 31 billion, which is five times the export value. Notably, many reports revealed a crucial laboratory diagnostics cost input due to anti-COVID-19 campaigns [62–64]; however, this could be excluded from the general accounting, and therefore the other costs for a patient per one-day stay singularly decreased during 2020–2021.

4. Discussion

The trial case study using LMDI decomposition on the changes to operating costs of public hospitals in Japan not only revealed the feasibility of the methodology, but also provided several referrable findings for policymaking towards financial sustainability.

4.1. Main Findings and Implications

By applying LMDI method to decompose the annual changes during 1996–2021 in operating costs of public hospitals in Japan, this study indicates the following: the recent institutional reform of public hospitals in Japan succeeded in reducing needless medical demands on public hospitals and raised the charge income, which on average led to an annual reduction of operating costs by JPY 9 million per hospital during 1996–2021. However, the reform failed to suppress the rapid increments in salary costs, material costs, and medicine costs, which added an annual increment of JPY 127 million per hospital to the increasing operating costs. Beyond the institutional reform, increased material and medicine costs are also thought to have resulted from currency devaluation and worldwide inflation. In addition, historical changes in population and people's overall consultation rates contributed an annual reduction of JPY 73 million per hospital. The COVID-19 pandemic shocked the healthcare system supported by public hospitals, but the impacts were internally offset among the factors.

These findings suggest further directions in system reform and policy making. First, it is necessary to establish and perfect an independent domestic medical supply chain to stabilize medical prices. Based on the empirical analysis, although the recent monetary easing policy led to the devaluation of the JPY and imported inflation, it contributed much to the export economy while the domestic consumer prices were kept low [50,65–69]. Second, information technologies such as 5G, big data analytic engines, remote medical consultation, and applications of Artificial Intelligence (AI) are expected to suppress the operating costs [70–75]. These measures help in downsizing the scale of public hospitals and improve the cost effectiveness [76,77]. Furthermore, policies such as cost-sharing can be proliferated with an aim to divert some of the inpatients from long-term stays in hospitals to community-based care facilities for conditions that do not necessitate medical intervention, especially in cases of elderly and chronic patients [78]. These policies may reduce the visit duration of single consultations and help in minimizing the overall investment for hospitals. Finally, it is necessary to improve the literacy and communications for citizens towards new technology protocols and health regulations, especially during a pandemic, to maximize the efficiency in reducing the operating costs of hospitals [79,80].

4.2. Methodological Considerations and Limitations

As a trial case study, here, a comprehensive decomposition of the annual changes in operating costs at public hospitals in Japan using LMDI is presented. Through the decomposition analysis, both historical influencing factors such as depopulation, hierarchical medical system reform, patient demand, and cost level changes, and temporary events such as the pandemic period, are quantitatively evaluated to determine the important driving forces that contributed the most to the increased hospital operating costs. However, the decomposition was still simple in comparison with similar studies in energy or transportation research fields. For example, costs for one patient per day can be further decomposed into the product of element input changes and price level changes, but we failed to access these data during the study. Further, compared to previous studies using correlation analysis, the number of influencing factors taken into account in this study was very limited because of the increasing difficulty of decomposing in a more detailed scale. This study revealed that decomposition using LMDI has advantages in quantitatively evaluating the contributions of influencing factors to the operating costs of hospitals, but is weak in selecting influencing factors, as many other theories support.

4.3. Future Research and Recommendations

According to the practice of LMDI decomposition in this study, future research can extend the decomposition in more detail, such as by decomposing the changes of the cost of one patient per day into the products of element input (the amount of labor forces, medicines, materials, building construction, and equipment that are input and the improvement in its structure) and price level (price changes of each element input in the medical

treatment). It is then possible to quantitatively check whether the efficiency of the element input has been improved and whether the price level is under control or not, and the degree of contribution of each element. Furthermore, future predictions of the operating costs of a hospital can be carried out if the data due to the future scenarios are input; this will be of great help in the quantitative assessment of the efficiency of the policies and measures against the increase in hospital operating costs.

5. Conclusions

The increase in operating costs against charge income is a critical problem for the financial management of public hospitals in Japan. To quantitatively identify the forces driving the increase in operating costs in recent decades, in this study, a complete decomposition analysis of public hospital operating costs was conducted using the LMDI method with corresponding definitions of the influencing factors based on statistical data covering the period from 1996 to 2021. The results indicate that the institutional reform of public hospitals was effective in increasing the efficiency of operating costs to charge income to some extent, while the continuously increasing operating cost level and a worsening cost structure played key roles in increasing the total operating costs rather than the charge income. In particular, the continuous rise in medicine costs caused by currency devaluation and worldwide inflation was a danger signal for the financial status of public hospitals. The COVID-19 pandemic caused a short-term shock to public hospital financial balances in the beginning of the year, but the situation seems to have returned to normal later on. In addition, historic changes in population, personal income levels, and health levels were found to have contributed significantly to a reduction in the total operating costs of public hospitals in Japan.

Learning from these findings, policymakers should pay more attention to material and medicine cost management during medical treatment. Particularly, establishing and perfecting independent domestic medicine production can contribute to stabilizing the variations in material and medicine prices arising from external factors. As experienced during the COVID-19 pandemic, new technologies, healthcare regulations, and policies should be quickly proliferated to society to bring major improvements in the financial balances of public hospitals during and after a pandemic. Short-term subsidies can fill part of the gap between a hospital's income and costs, but cannot essentially solve the long-term imbalance between these factors. With the ongoing institutional reform of public hospitals, a strategic national plan for building a stable material and medicine supply chain will be indispensable.

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