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Differences in inpatient performance of public general hospitals following implementation of a points-counting payment based on diagnosis-related group: a robust multiple interrupted time series study in Wenzhou, China

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ABSTRACT

Objectives This study measures the differences in inpatient performance after a points-counting payment policy based on diagnosis-related group (DRG) was implemented. The point value is dynamic; its change depends on the annual DRGs' cost settlements and points of the current year, which are calculated at the beginning of the following year.

Design A longitudinal study using a robust multiple interrupted time series model to evaluate service performance following policy implementation.

Setting Twenty-two public general hospitals (8 tertiary institutions and 14 secondary institutions) in Wenzhou, China.

Intervention The intervention was implemented in January 2020.

Outcome measures The indicators were case mix index (CMI), cost per hospitalisation (CPH), average length of stay (ALOS), cost efficiency index (CEI) and time efficiency index (TEI). The study employed the means of these indicators.

Results The impact of COVID-19, which reached Zhejiang Province at the end of January 2020, was temporary given rapid containment following strict control measures. After the intervention, except for the ALOS mean, the change-points for the other outcomes ($p<0.05$) in tertiary and secondary institutions were inconsistent. The CMI mean turned to uptrend in tertiary ($p<0.01$) and secondary ($p<0.0001$) institutions compared with before. Although the slope of the CPH mean did not change ($p>0.05$), the uptrend of the CEI mean in tertiary institutions alleviated ($p<0.05$) and further increased ($p<0.05$) in secondary institutions. The slopes of the ALOS and TEI mean in secondary institutions changed ($p<0.05$), but not in tertiary institutions ($p>0.05$).

Conclusions This study showed a positive effect of the DRG policy in Wenzhou, even during COVID-19. The policy can motivate public general hospitals to improve their comprehensive capacity and mitigate discrepancies in treatment expenses efficiency for similar diseases. Policymakers are interested in whether the reform successfully motivates hospitals to strengthen their internal impetus and improve their performance, and this is supported by this study.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A robust multiple interrupted time series (R-MITS) model does not assume that the effect of an intervention is instantaneous and allows the presence of a potentially lagged (or anticipatory) effect, which match the characteristics of the diagnosis-related group (DRG) policy.

⇒ R-MITS estimates the global change-point at which the effect of an intervention initiates for the entire health system, rather than removing some points as decided by the study team.

⇒ R-MITS can capture mean differences in variability and autocorrelation of time series changes, improve validity and reduce bias to obtain more accurate estimates.

⇒ Due to inner differences in different hospitals, DRG-related indicators were selected and subgroup analysis was done to make the performance evaluation more homogeneous and comparable.

⇒ Despite failing to use a difference-in-differences method, this study conducted R-MITS analysis to enhance the relationship between the evolution of results and the intervention.

INTRODUCTION

The healthcare systems in most countries are confronted with increasing pressure, especially with regard to the growing demand for healthcare services, while struggling with growing medical insurance expenditures.[1 2] Before the diagnosis-related group (DRG) payment system, inpatient medical services in China were mainly using fee-for-service, which easily results in overtreatment and restrains improvement in

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service performance. As a prepayment system, the DRG payment system, which originated in the USA in the 1970s, involves the adoption of a standard pricing framework that provides equity across healthcare providers in terms of payments for the same types of services.[3 4] Subsequently, many countries and regions have adopted the DRG medical insurance payment system in attempts to contain expenditure and increase the transparency, efficiency and safety of their healthcare systems.[4–7] However, the classification rules of DRG require high-quality medical record homepage data and judgement from physicians. Therefore, the roll-out of DRG payment system has some challenges in middle-income and low-income countries with limited resources.[8]

Maximising hospitals' service performance has been prioritised worldwide,[9] and this has also influenced the primary content of the healthcare system reform in China.[10] Before 2020, no province in China has implemented the DRG payment system in all public hospitals because this payment system is costly and requires advanced information systems. To advance the reform of its healthcare system, China has devoted itself to the adoption of the DRG payment system as one of the main payment methods and to optimise the payment rules and relevant mechanisms in order to meet Chinese healthcare conditions.[7 11] China officially announced the implementation of the DRG payment system in 30 pilot national monitoring cities and set the following arrangement: that the initial implementation work commence in 2019, that the simulated operation commence in 2020 and that the actual payment commence in 2021.[12 13] The DRG payment reform, as an important means of regulating medical behaviours in China,[14] can revolutionise the healthcare system. It involves several complementary elements: a mechanism for allocating funding for hospital services, one for hospital management and a provider payment mechanism within the broader healthcare financing system.[3] Under the funding constraints of DRG total budget management, hospitals have to respond aggressively. The implementation of the DRG payment reform requires hospitals to be proactive with regard to the quality of medical records (like more long coding time to ensure the quality of case grouping) and an improvement in the performance of their healthcare services to avoid losses after policy implementation. Under the given pricing standard, hospitals are responsible for their losses in cases where medical costs exceed the pricing standard. Such a response can have a wide-ranging effect,[15 16] especially if it can affect hospitals' direct interests that motivate them to regulate clinical behaviours and transform their management from passive to positive, which in turn can improve service performance.

China places great importance on the impact of the DRG payment system on healthcare performance because it can influence the overall arrangement and progress; however, empirical evidence of its impact in China is still inadequate. Before the effect on service performance can be assessed, it is necessary to obtain a comprehensive understanding of the policy's influence and to optimise the study design in order to achieve an optimal evaluation and manage policymakers' expectations. Above all, the time at which the payment reform was initiated, announced and publicised could impact its outcomes.[17] It sent a strong signal to those hospitals whose cities were not among the national pilots but then decided to implement the DRG payment system. On the one hand, it may have encouraged hospitals to change their management approaches to pursue a more positive adaption of the new payment method, such as by managing medical performance based on DRG data,[18] improving information levels[19] and strengthening the quality of diagnoses coding.[20] Such measures can provide an early foundation for the formal implementation of the DRG payment system. On the other hand, it is also reasonable to assume that the obvious behavioural changes adopted by hospitals occurred after the official implementation, possibly due to certain problems concerning the requisite technology and operation of the DRG payment approach.[21] Those hospitals with relatively weak basic conditions required more intensive policy adaptation, such as training personnel in DRG-associated tasks and improving familiarity with the diagnostic and operational codes for diseases. It can affect the reaction time and the degree of importance across different hospitals to some extent; however, previous studies may have neglected to include the time until the policy's effects manifested.[22 23] Subsequently, the ability of hospitals to improve their performance is likely to have varied across different institution levels, which is an important factor in identifying the effects of the payment policy. The Chinese Health Commission divides medical institutions into three levels, according to their tasks and functions, to form a hierarchical medical system: primary, secondary and tertiary hospitals.[24] Tertiary hospitals are the main cost control objects, whose insurance expenditures account for the bulk of medical insurance funds. Previous studies have analysed them as subgroups in healthcare,[25] but few have done assessment of the effects of the DRG payment system on service performance across hospitals. Given that Chinese healthcare is provided almost by state-owned public general hospitals,[26] it is important to explore whether there are differences across subgroups in terms of the effects.[27]

On 12 November 2019, Zhejiang Province issued interim measures on DRG' points-counting payment (PCP) for hospitalisation expenses in basic medical insurance that required all subprovincial and prefecture-level cities to implement PCP based on DRG under the total budget management from January 2020.[28] The points of a given case are determined as follows:

$$\begin{aligned}\text{Points (case)} &= \text{corresponding DRG benchmark points}\\ &\quad \times \text{difference coefficient}\end{aligned}$$

The health insurance department of every subprovincial or prefecture-level city sets the calculation standards for benchmark points and difference coefficients. The

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health insurance department of the district or county-level city calculates the point value (PV). PV is dynamic and changes depending on the current annual DRGs' cost settlement and points, which are calculated at the beginning of the following year. PV is determined as follows:

$$PV = \frac{\text{Annual DRG cost settlement in a district or county-level city}}{\text{Annual DRG points in this district or county-level city}}$$

The revenue of the DRG payment for a hospital is determined as follows:

$$\text{Revenue (Hospital)} = \text{Annualpoints (Hospital)} \times PV$$

This PCP based on DRG applies the principle of the work point theory with reference to the weighting criteria of each DRG to establish the relative price relationship between medical costs and weights of different disease groups, and then converts the points of each DRG group using these points to allocate the regional health insurance. Zhejiang classifies its hospitalisation cases into 1006 DRGs based on the nation's 618 DRGs grouping scheme. Zhejiang is the first province to announce enforcement of DRG payment system across country; whether the PCP method based on DRG can exert a strong motivation on hospitals to improve their service performance is important for China, but it is still an open topic. Given this, this study takes Wenzhou in Zhejiang Province as a sample city to evaluate hospital performance before and after the implementation of the DRG reform between 2018 and 2021 in public general hospitals from the institution-level perspectives.

METHODS

Data source and sample size

Wenzhou City lies in the southeast of Zhejiang Province. In 2021, the resident population was 9.6450 million—the second most populous city in Zhejiang. It has a wealth of successful experience in reform and strong comprehensive medical service,[29] besides, its DRG policy implementation process and healthcare system structure are similar to other cities, and which can therefore act as a case for estimating the effects of the PCP on public general hospitals. Wenzhou performed upfront preparations for the DRG payment method, with effect from 20 May 2019, earlier than the other cities. Since then, more than 21 related symposia have been presented among hospitals. In 2019, the Wenzhou Healthcare Security Administration conducted disease grouping and cost measurement for the past 3 years. The base data were collected from 161 medical institutions in the city that offer hospitalisation. After grouping by DRG, hospitalisation cases were divided into 912 DRGs. Among them were 55 DRGs where the number of cases was ≤5 and 857 DRGs where the number of cases was >5, with their coefficient of variation <1; the reduction in variance was 75.04% and the cost differences across groups were all >20%, which reached the national technical specifications for DRG grouping and payment. On 13 December 2019, the Wenzhou local government held a publicity meeting on the payment policy and issued a detailed draft of the rules, after which it began communicating with hospitals to optimise the policy. On 27 December 2019, the DRG' Points Counting Payment Implementation Rules was issued and scheduled for implementation in January 2020.[30] Figure 1 shows the timeline of the implementation of the DRG payment policy in 2019.

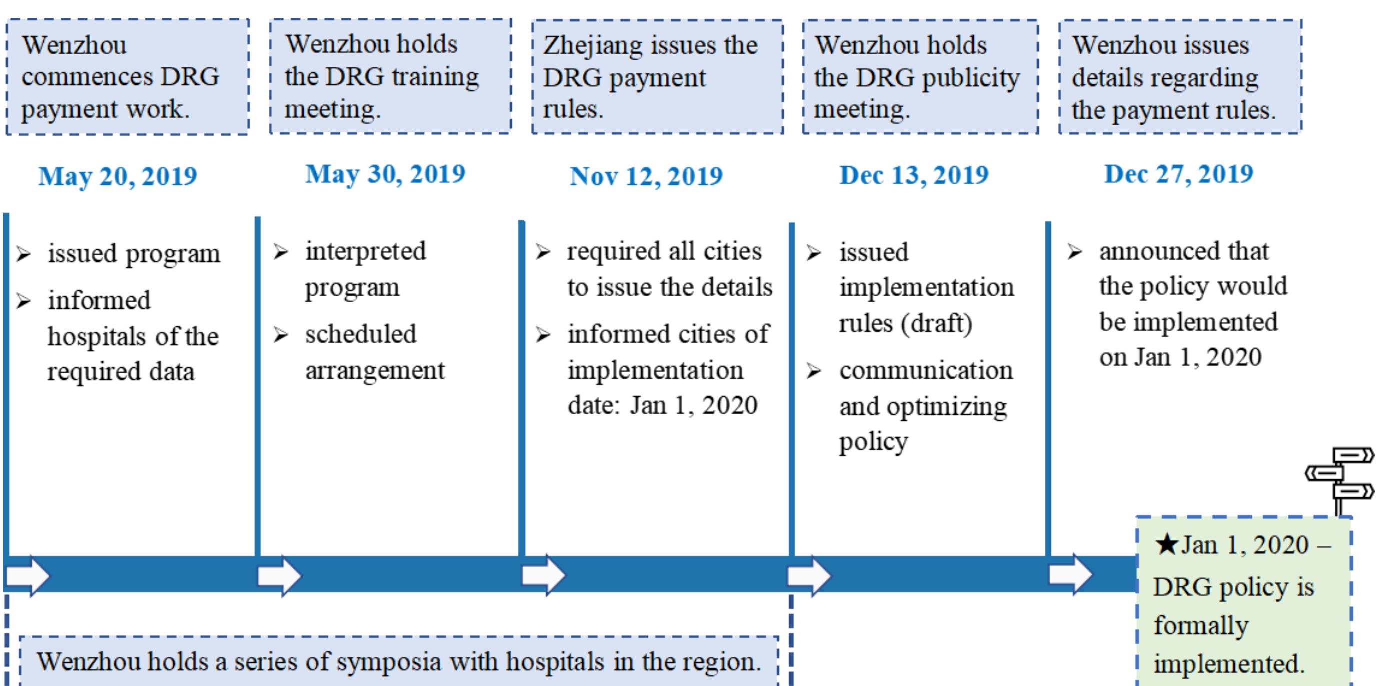

Figure 1 Implementation process for the diagnosis-related group (DRG) payment policy in 2019 in Wenzhou.

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According to Chinese hospital classification and management standards, primary hospitals are hospitals that provide preventive, medical, healthcare and rehabilitation services directly to a community of a certain population. Secondary hospitals are regional hospitals that provide comprehensive medical and health services to multiple communities and undertake certain teaching and research. Tertiary hospitals are hospitals above the regional level that provide high-level specialised medical services to several regions and perform higher medical education and research. The above-primary-level public general hospitals in Wenzhou amounted to 22 institutions, which consisted of 8 tertiary hospitals and 14 secondary hospitals. In 2021, the number of discharged cases in above-primary-level public general hospitals in Wenzhou was 840 342, accounting for 98.79% of the 850 652 discharged cases. The intervention was implemented officially in 2020; the time series data collected from these 22 institutions spanned from 2018 to 2021: before implementation: 2018–2019; after implementation: 2020–2021. The data were collected from the Zhejiang Hospital Quality Management and Performance Evaluation Platform, which was developed by the Zhejiang Provincial Health Commission. The platform launched in 2017 and reviewed the quality of the data uploaded by each hospital by logic verification and key quality control index monthly before evaluating their performance. The platform allows administrative departments and medical institutions to query DRG' performance data. In 2021, it evaluated 424 above-primary-level hospitals in Zhejiang Province.

Indicators

This study used five performance indicators calculated by the Zhejiang Hospital Quality Management and Performance Evaluation Platform that reflect the medical capacity and consumption of medical resources. The five performance indicators were case mix index (CMI), cost per hospitalisation (CPH), cost efficiency index (CEI), average length of stay (ALOS) and time efficiency index (TEI). Among them, the CMI, CEI and TEI derive from the DRG system and have been found to have excellent homogeneous comparability.[31–34] The following are the definitions and calculations of CMI, CEI and TEI as determined by the Zhejiang Provincial Health Commission.

CMI reflects the average comprehensive medical ability of a medical institution and the average seriousness or difficulty of diseases. The calculation method is:

$$\text{CMI} = \frac{\text{Total weight}}{\text{Number of cases in region}}$$

$$\text{Total weight} = \sum \text{Each DRG weight} \times \text{Number of cases in each DRG}$$

CEI reflects the cost of treating similar diseases in this region. A CEI value close to 1 suggests that, for the region in question, the cost efficiency is close to the average level; values below 1 or above 1 suggest that the efficiency is above or below the average level, respectively.

$$\text{CEI} = \frac{\sum_j k_j^c n_j}{\sum_j n_j}$$

$$\textit{Cost ratio}(k^c) = \frac{\textit{average cost of a DRG in hospital } (c_i)}{\textit{average cost of a DRG in region } (C_i)}$$

where n_j represents the number of cases in DRG_j, and CEI is the weighted average of k^c.

TEI reflects the time spent treating similar diseases in the region. A TEI value close to 1 suggests that, for the region in question, the time efficiency is close to the average level; values below 1 or above 1 suggest that the efficiency is above or below the average level, respectively.

$$\text{TEI} = \frac{\sum_j k_j^l n_j}{\sum_j n_j}$$

$$\textit{Average length of stay ratio } (k^l) = \frac{\textit{average length of a DRG in hospital } (l_i)}{\textit{average length of a DRG in region } (L_i)}$$

where n_j represents the number of cases in DRG_j, and TEI is the weighted average of k^l.

To reflect the differences in performance from the institutional-level perspectives, this study employed the mean of the indicators in total institutions, tertiary institutions and secondary institutions, respectively.

Statistical analysis

Interrupted time series has become a core study design for the evaluation of health policies.[17] This study used a robust multiple interrupted time series (R-MITS) model, which has several advantages over the traditional designs of interrupted time series (ITS).[35–37] Above all, R-MITS borrows information from all microsystems to estimate the global change-point; that is, it determines the time point at which the effect of the intervention initiates for the entire health system, rather than removing some points as decided by the study team.[36] An intervention to increase the stability and predictability of an outcome may have decreased outcome variability and increased autocorrelation.[37] Given that decreasing outcome variability can contribute to less extreme values while increasing autocorrelation can contribute to a more predictable outcome, it is important to capture alongside mean differences in variability and autocorrelation. Compared with traditional designs, this R-MITS model can capture all the aforementioned time series changes. Furthermore, it does not assume that the intervention is instantaneous and allows the effect of the intervention to be abrupt or gradual, thus allowing the presence of a potentially lagged (or anticipatory) effect. It can obtain more accurate estimates, which can further improve internal and external validity and reduce bias.[35 38] This robust model has been widely adopted to evaluate improvements in care quality both at the system and unit level[38]; the effectiveness of a quality improvement initiative for reducing cardiac arrests among infants and children[39]; the impact of trauma centre accreditation on mortality and complications[40];

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Table 1 Unit-specific yearly results prepolicy and postpolicy implementation

Unit	Year	CMI mean	CPH mean	CEI mean	ALOS mean	TEI mean
Total institutions	2018	0.7986	8721.0482	0.8841	8.2700	0.9664
	2019	0.7852	8775.5059	0.8695	8.0264	0.9682
	2020	0.8344	9418.2600	0.9077	8.1859	1.0000
	2021	0.8590	9484.7664	0.9286	7.7677	1.0123
Tertiary institutions	2018	0.8678	12 658.6038	1.1238	8.5188	1.0288
	2019	0.8641	12 569.7275	1.0950	7.8675	1.0075
	2020	0.8864	13 192.7838	1.1100	7.6925	0.9925
	2021	0.9041	12 951.4875	1.1075	7.0475	0.9875
Secondary institutions	2018	0.7590	6471.0164	0.7471	8.1279	0.9307
	2019	0.7402	6607.3793	0.7407	8.1171	0.9457
	2020	0.8047	7261.3893	0.7921	8.4679	1.0043
	2021	0.8332	7503.7829	0.8264	8.1793	1.0264

Pre-implementation: from 2018 to 2019; post implementation: from 2020 to 2021.
ALOS, average length of stay; CEI, cost efficiency index; CMI, case mix index; CPH, cost per hospitalisation; TEI, time efficiency index.

and the effectiveness of chest pain units in observation times, diagnostic agreement and emergency department readmission and hospitalisations.[41] The R-MITS model is shown in online supplemental appendix A.

Patient and public involvement

None.

RESULTS

Descriptive analysis

The yearly outcomes for every target indicator for the period of 2018–2021 (representing pre-implementation and post implementation) are shown in table 1.

The yearly results for the CMI mean in tertiary institutions decreased from 0.8678 to 0.8641 before 2020 and increased from 0.8864 to 0.9041 after 2020; in secondary institutions, it decreased from 0.7590 to 0.7402 before 2020 and increased from 0.8047 to 0.8332 after 2020.

The CPH mean in tertiary institutions decreased from 12 658.6038 to 12 569.7275 before 2020 and decreased from 13 192.7838 to 12 951.4875 after 2020; in secondary institutions, it increased from 6471.0164 to 7503.7829 yearly before and after 2020. The CEI mean in tertiary institutions decreased from 1.1238 to 1.0950 before 2020 and decreased from 1.1100 to 1.1075 after 2020; in secondary institutions, it decreased from 0.7471 to 0.7407 before 2020 and increased from 0.7921 to 0.8264 after 2020.

The ALOS mean in tertiary institutions decreased from 8.5188 to 7.0475 yearly before and after 2020; in secondary institutions, it decreased from 8.1279 to 8.1171 before 2020 and decreased from 8.4679 to 8.1793 after 2020. The TEI mean in tertiary institutions decreased from 1.0288 to 0.9875 yearly before and after 2020; in secondary institutions, it increased from 0.9307 to 1.0264 yearly before and after 2020.

R-MITS analysis

The estimated changes using R-MITS for all samples and subgroups are shown in table 2. The fitted regression lines are shown in figure 2. The estimates for the stochastic component parameters are shown in online supplemental appendix B, and the residuals of the estimated model and autocorrelation functions are as expected and are shown in online supplemental appendix 1–5, demonstrating that the curves of the measures included for both pregroup and postgroup are linear and independent.

The R-MITS results show the following:

For the CMI mean in tertiary institutions, the effect change-point was estimated for February 2020 ($p<0.05$), with the slope changing from −0.0001 to 0.0008 ($p<0.01$); the effect change-point in secondary institutions was estimated for January 2020 ($p<0.0001$), with the slope changing from −0.0012 to 0.0019 ($p<0.0001$).

For the CPH mean in tertiary institutions, the effect change-point was estimated for January 2020 ($p<0.01$), with the slope changing from −18.7100 to −43.3100 ($p>0.05$); in secondary institutions, the effect change-point was estimated for April 2020 ($p<0.001$), with the slope changing from 8.5540 to −0.8039 ($p>0.05$). For the CEI mean in tertiary institutions, the effect change-point was estimated for June 2019 ($p<0.0001$), with the slope changing from 0.0020 to 0.0005 ($p<0.05$); in secondary institutions, the effect change-point was estimated for April 2020 ($p<0.0001$), with the slope changing from 0.0003 to 0.0015 ($p<0.05$).

For the ALOS mean in tertiary institutions, the effect change-point was estimated for January 2020 ($p<0.05$), with the slope changing from −0.0488 to −0.0618 ($p>0.05$); in secondary institutions, the effect change-point was estimated for January 2020 ($p<0.0001$), with the slope changing from −0.0041 to −0.0261 ($p<0.01$). For the TEI mean in tertiary institutions, the effect change-point was estimated for June 2020 ($p>0.05$), with the slope changing from −0.0010 to −0.0005 ($p>0.05$); in secondary

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Table 2 Unit-specific changes estimated by R-MITS preintervention and postintervention

Outcomes	Unit	Change-points	Changes in slope			Changes in intercept
			Prechange (β_{i1}^{τ})	Postchange ($\beta_{i1}^{\tau}+\Delta_i^{\tau}$)	Change (Δ_i^{τ})	(δ_i^{τ})
CMI mean	Total institutions	March 2020****	−0.0002	0.0013	0.0015****	0.0100
	Tertiary institutions	February 2020*	−0.0001	0.0008	0.0009**	0.0015
	Secondary institutions	January 2020****	−0.0012	0.0019	0.0031****	−0.0099
CPH mean	Total institutions	January 2020***	−6.4420	−5.2860	1.1560	909.9000**
	Tertiary institutions	January 2020**	−18.7100	−43.3100	−24.6000	1957.0000***
	Secondary institutions	April 2020***	8.5540	−0.8039	−9.3580	1075.0000***
CEI mean	Total institutions	June 2019****	0.0011	0.0024	0.0013**	−0.0505**
	Tertiary institutions	June 2019****	0.0020	0.0005	−0.0015*	−0.0238
	Secondary institutions	April 2020****	0.0003	0.0015	0.0012*	0.0115
ALOS mean	Total institutions	January 2020****	−0.0202	−0.0392	−0.0190*	1.0710***
	Tertiary institutions	January 2020*	−0.0488	−0.0618	−0.0130	0.9115*
	Secondary institutions	January 2020****	−0.0041	−0.0261	−0.0220**	1.1540***
TEI mean	Total institutions	April 2020***	0.0006	−0.0005	−0.0011	0.0659**
	Tertiary institutions	June 2020	−0.0010	−0.0005	0.0005	−0.0231
	Secondary institutions	April 2020****	0.0016	−0.0002	−0.0018*	0.1102***

Significance level α=0.05.
*P<0.05, **P<0.01, ***P<0.001, ****P<0.0001.
ALOS, average length of stay; CEI, cost efficiency index; CMI, case mix index; CPH, cost per hospitalisation; R-MITS, robust multiple interrupted time series; TEI, time efficiency index.

institutions, the effect change-point was estimated for April 2020 (p<0.0001), with the slope changing from 0.0016 to −0.0002 (p<0.05).

DISCUSSION

With limited and stretched healthcare resources, it is important for hospitals to further improve the performance of their medical services after the new policy implementation. In general, the results from all samples and subgroups seem positive from various perspectives.

For all samples and subgroups, this study found that the CMI mean showed a downward curve before the change, but increased after the change, from which it can be inferred that the policy implementation likely motivated these hospitals to devote themselves to improving the CMI. According to the payment rules, improving the CMI can contribute to securing more DRG points, thereby acquiring more medical insurance funds. The study indicated that the CMI change lagged 2 months after the DRG policy was officially implemented, which may

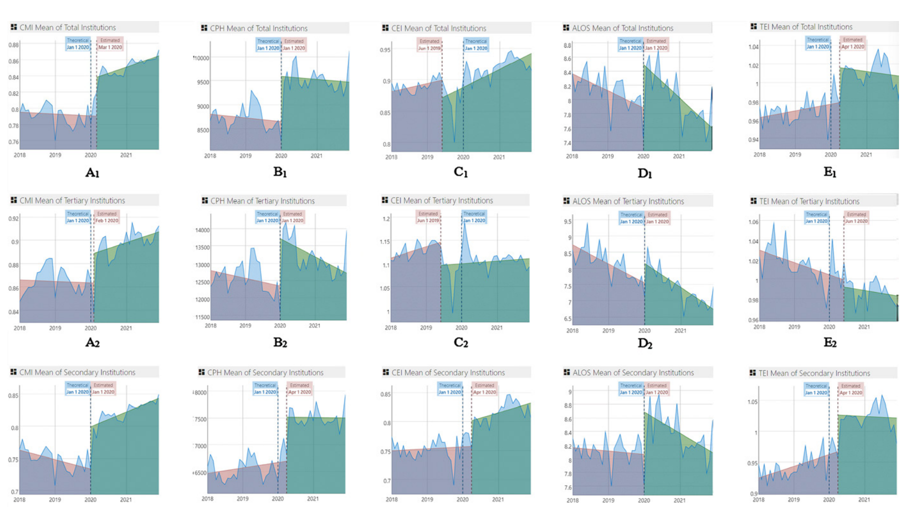

Figure 2 Fitted regression lines for institutions before and after change-points. A_i, B_i, C_i, D_i and E_i are the fitted regression lines of the outcomes (CMI mean, CPH mean, CEI mean, ALOS mean, TEI mean) in total institutions (*i*=1), tertiary institutions (*i*=2) and secondary institutions (*i*=3), respectively. ALOS, average length of stay; CEI, cost efficiency index; CMI, case mix index; CPH, cost per hospitalisation; TEI, time efficiency index.

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result from the difficulty in strengthening comprehensive ability immediately even if they have stronger motivation than before. This study also found that the CMI mean in tertiary institutions changed later and improved slower than in secondary institutions after the change. The CMI in tertiary institutions has already reached high levels and its improvement would require more effort than secondary institutions. Due to Chinese citizens being at liberty to choose healthcare services at any institution, tertiary institutions with higher levels of comprehensive medical strength can attract more patients under the siphon effect.[42 43] With service accessibility improving, patients would rather visit tertiary hospitals, even though most of their illnesses are not severe.[44 45] As a result, it improved the number of low-related weight cases to be treated at tertiary institutions, which constrained the improvement in CMI and also affected the hierarchic healthcare treatment system performance for a long time. Significantly, under the influence of the DRG payment rules, tertiary institutions tended to treat more serious diseases (that possess high relative weights) and were willing to transfer the more common or easy-to-treat cases to lower-grade institutions.[21] Subsequently, the capacity to treat diseases of high relative weights can be increased, which can contribute to improving their CMI. In a sense, the implementation of the DRG policy can promote the hierarchic healthcare treatment system performing its intended role in China.

After the policy intervention, the CEI mean in all samples increased at a faster rate towards 1, from which it can be inferred that the policy can further motivate these institutions to narrow the differences across institutions in terms of the cost of treating similar diseases. Interestingly, the results showed that the CEI mean changed in June 2019, following the commencement of the policy reform in May 2019. Different from fee-for-service, the rule of the DRG payment is that 'excess expenditures will no longer be reimbursed and the balance will be retained',[46] meaning ultra-high-cost inpatient cases in the same group will cause financial losses for hospitals. The introduction of the policy could increase cost control consciousness and motivate associated management behaviours,[3 47] like improving the coding quality of DRG data,[21] which made the response of these institutions to strengthening the CEI faster than the other indicators. Focusing only on changes in subgroups, this study showed that tertiary institutions reacted faster than secondary institutions to the DRG policy in terms of CEI; the CEI mean in tertiary institutions remained higher than 1, while this remained lower than 1 in secondary institutions before and after the change. As is known, the CPH in tertiary institutions is higher than secondary institutions; similarly, the phenomenon of spending high costs on similar diseases was more common in tertiary institutions, which resulted in their high CEI. Because medical equipment, technical levels, drugs and consumables in tertiary institutions were more advanced, they attract higher expenses.[13] It was also found that the uptrend of the CEI mean in tertiary institutions was slower than before; the CEI mean in secondary institutions changed faster towards 1, from which it can be inferred that the difference in tertiary and secondary institutions was mitigated by the intervention.

A decrease in the length of stay can be either positive or negative for individual patients and for the health system as a whole.[48] ALOS reflects the average time of healthcare resources taken up by each inpatient; the longer it takes, the more likely the hospital makes a loss. It may be the reason that the DRG policymakers are strengthening the readmission rate monitoring, and some penalties,[28 30] because it is not guaranteed that all hospitals will not intentionally discharge inpatients early to minimise their losses or to increase revenues.[21] Certainly, decreasing TEI can be reasonable, but it requires prior improvement of medical levels across hospitals. After the intervention, this study found that the TEI mean in tertiary institutions did not change significantly, while it did in secondary institutions. As is known, compared with secondary institutions, tertiary institutions have stronger medical service capacity and can better treat inpatients with similar diseases. As a result, tertiary institutions require much more efforts to further reduce the TEI in a short time. Besides, after the policy was implemented, the CMI mean both in tertiary and secondary institutions, which decreased initially and then increased, can be inferred as improvement in the percentage of serious or complex diseases treated in these institutions, which means hospitals require more time to treat inpatients. Under the CMI mean, which decreased initially and then increased, secondary institutions have a huge potential to improve and successfully change the TEI, compared with tertiary institutions.

The findings presented here should be generalised with caution. The impact of COVID-19 reached Zhejiang Province (to where Wenzhou is located) at the end of January; fortunately, the setback was temporary due to the implementation of strict prevention and control measures, and recovery gradually occurred after February 2020. Nevertheless, it may have unavoidably resulted in decreasing patient visits and hospital revenues, while increasing operation costs and medical efficiency, which may hinder the improvement of these selected indicators. We could have minimised the disruption of COVID-19 by removing data from the early years of the policy, but we did not do so because it would have been too subjective. The R-MITS model can identify inferences regarding the estimation of global change-points across units, rather than removing some series as decided by the study team. In such an external environment, the implementation of the DRG payment policy would be timely and may make up for the negative impact of the epidemic, which could motivate cost control consciousness and management behaviours.[3 47] Under the DRG payment policy, hospitals would make adjustments to strengthen service performance; otherwise, the revenue loss would be huge. Theoretically, the policy can guide high-grade-level hospitals to focus on the treatment of more complex and severe diseases and the breakthrough of medical service level,

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while returning routine and common diseases to low-grade-level hospitals for treatment in order to improve the CMI indicator. In addition, motivating hospitals to improve medical levels and efficiency can promote other indicators. This study showed that the DRG policy had positive effects on hospital performance, even during COVID-19.

Regarding the analysis method, we were unable to apply the difference-in-differences method because the medical institutions of Zhejiang Province, that could pay for basic medical insurance funds, were all required to implement the DRG payment policy, including Wenzhou. In addition, we could not obtain data from the public general hospitals outside Zhejiang Province where the DRG or other payment reforms (like the Diagnosis Intervention Packet payment[49]) were not implemented, under the process of the nationwide payment reform. Fortunately, R-MITS is an optimised version of ITS, the strengths of which include enhancing the relationship between the evolution of results and the intervention of study. Also, the subjects of this study were public general hospitals; however, we collected data from secondary and tertiary public general hospitals, excluding primary hospitals that did not have time series data for DRG-related indicators preintervention and postintervention. DRG indicators can homogeneously compare medical performance, but their calculations are more dependent on the quality of the homepage of inpatient medical records than traditional indicators, especially disease coding quality. CMI reflects the average level of medical technology and complexity of the diseases attended to by each hospital; CEI and TEI reflect the relative efficiency of CPH or ALOS, which are calculated based on DRG. This evaluation was conducted close to the intervention's time, which might not produce the same results as other evaluations carried out at a later date.

CONCLUSIONS

Despite the inevitable impact of COVID-19 on hospitals, the design of this study succeeded in revealing some anticipated and positive effects of the DRG policy on hospitalisation performance. Implementing the policy can motivate public general hospitals to improve their medical comprehensive capacity and mitigate discrepancies in treatment expenses efficiency for similar diseases across different-grade institutions. Hospitals first focused on strengthening hospitalisation efficiency, although there were differences between tertiary and secondary hospitals when responding to the DRG policy. One of the original intentions of the reform is to motivate hospitals to form the internal impetus to improve their performance, changing the less effective development mode of the past. From this perspective, our results further supported the target of the reform in China.

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Patient consent for publication Not required.

Ethics approval The study does not involve human participants. Approvals regarding data access for the study were obtained from the Health Information Center, Health Commission of Wenzhou, China.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data are available upon reasonable request with the permission of Health Information Center in the region.

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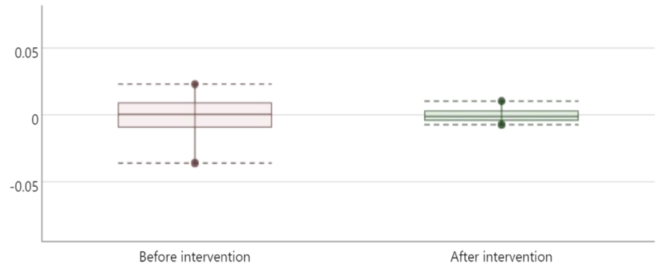
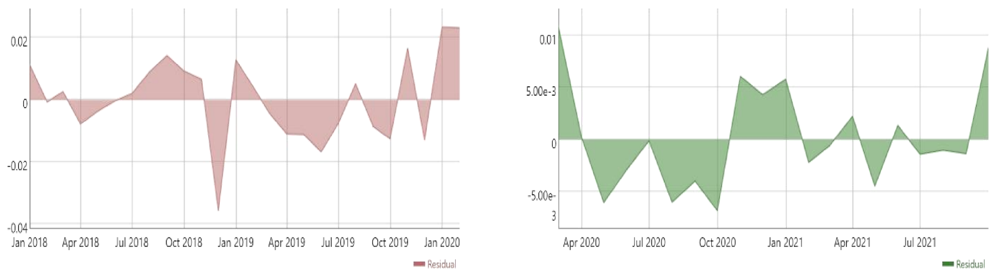
Appendix 1 through 5: Residuals and auto-correlation functions for outcomes

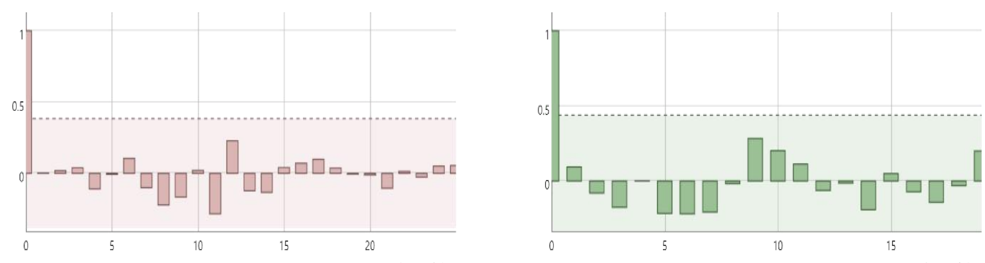
Appendix 1: Case-mix index (CMI) mean



Box plot of the residuals

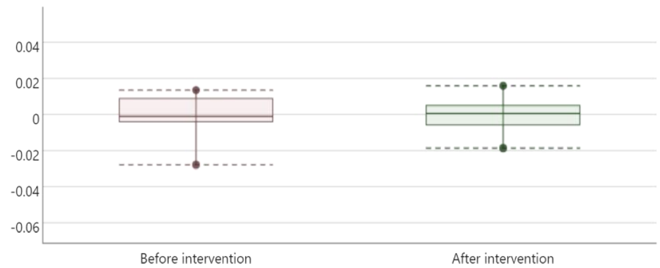


Residuals (before and after change-point)



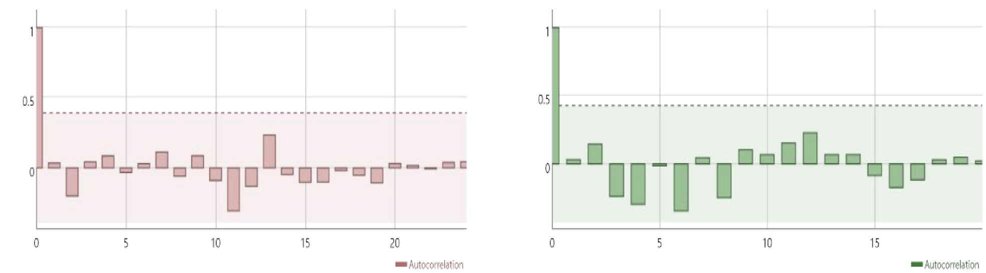
Auto-correlation function (before change-point)

Plots 1: CMI mean in total institutions



Box plot of the residuals

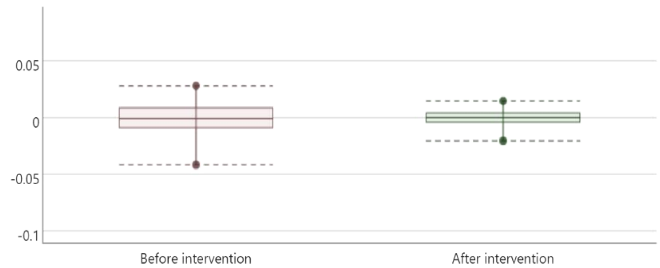
Residuals (before and after change-point)



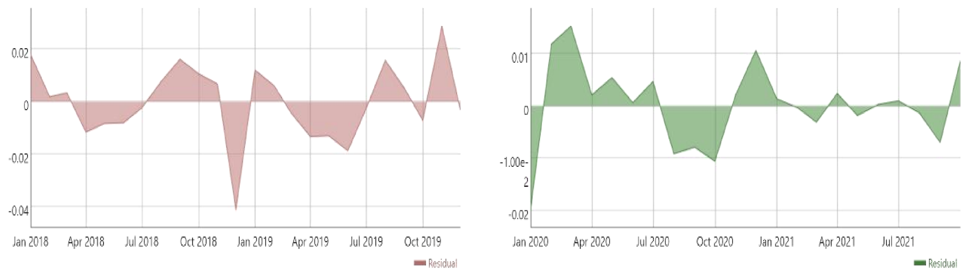
Auto-correlation function (before change-point)

Plots 2: CMI mean in tertiary institutions

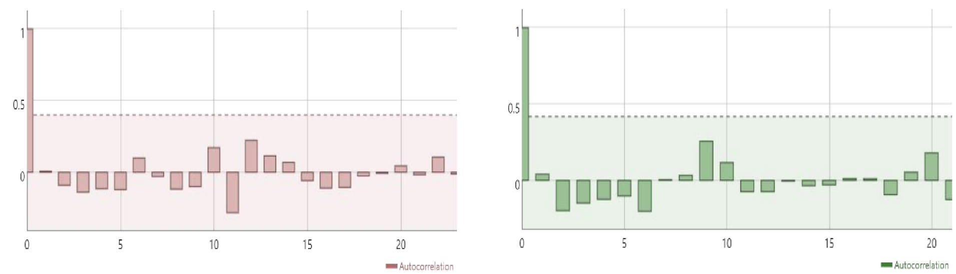
Information Classification: General



Box plot of the residuals



Residuals (before and after change-point)



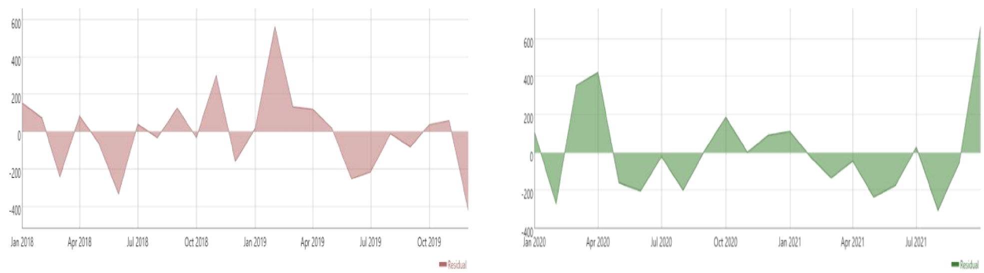
Auto-correlation function (before and after change-point)

Plots 3: CMI mean in secondary institutions

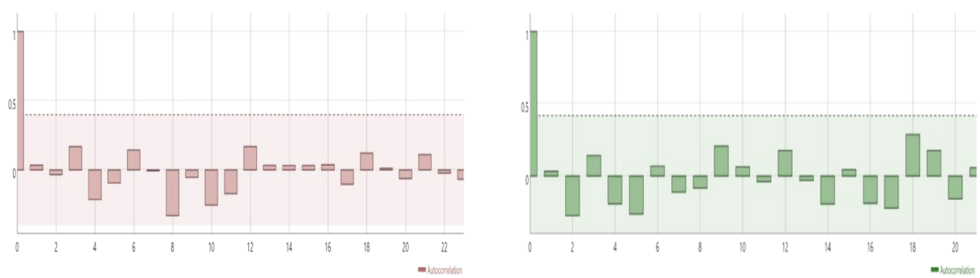
Information Classification: General

Appendix 2: Cost per hospitalization (CPH) mean

Box plot of the residuals



Residuals (before and after change-point)

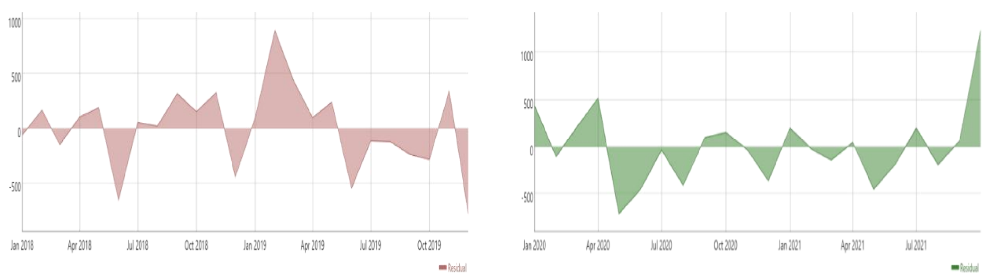


Auto-correlation function (before and after change-point)

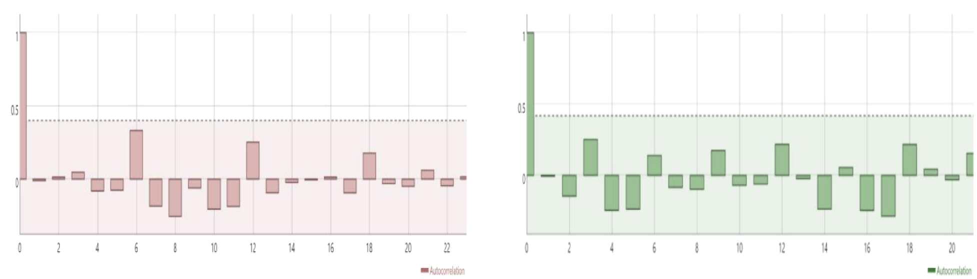
Plots 1: CPH mean in total institutions

Information Classification: General

Box plot of the residuals



Residuals (before and after change-point)



Auto-correlation function (before change-point)

Plots 2: CPH mean in tertiary institutions

Information Classification: General

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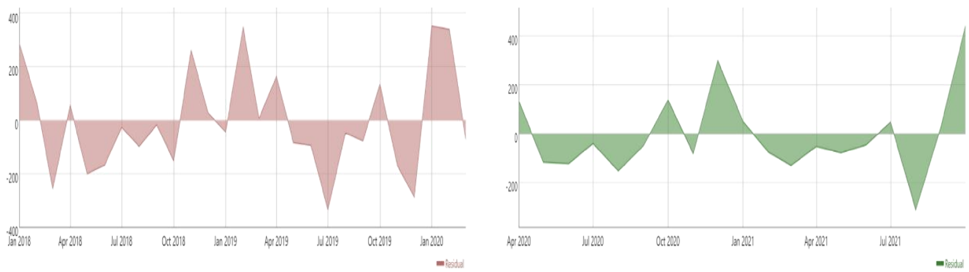
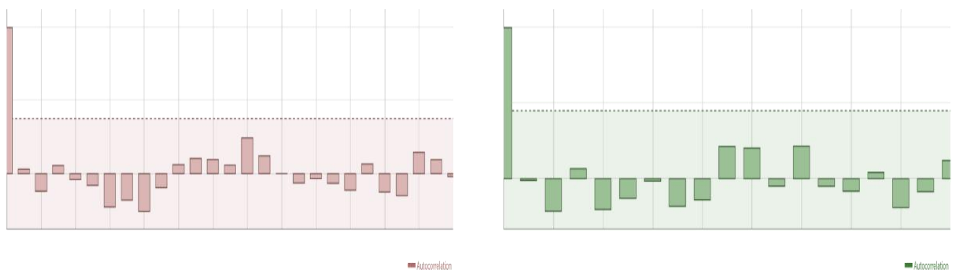
Box plot of the residuals



Residuals (before and after change-point)

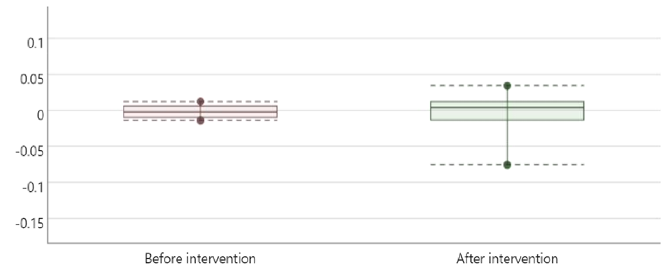


Auto-correlation function (before and after change-point)

Plots 3: CPH mean in secondary institutions

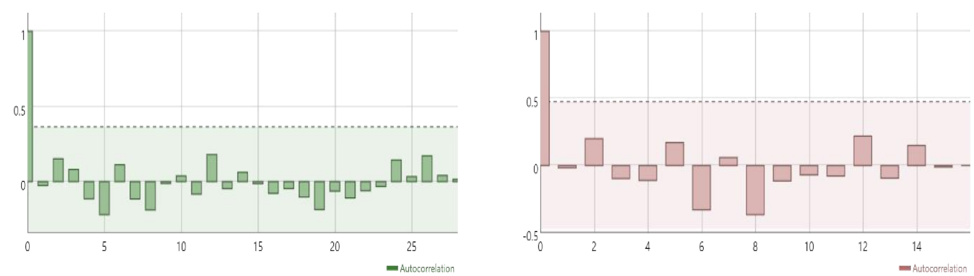
Information Classification: General

Appendix 3: Cost efficiency index (CEI) mean



Box plot of the residuals

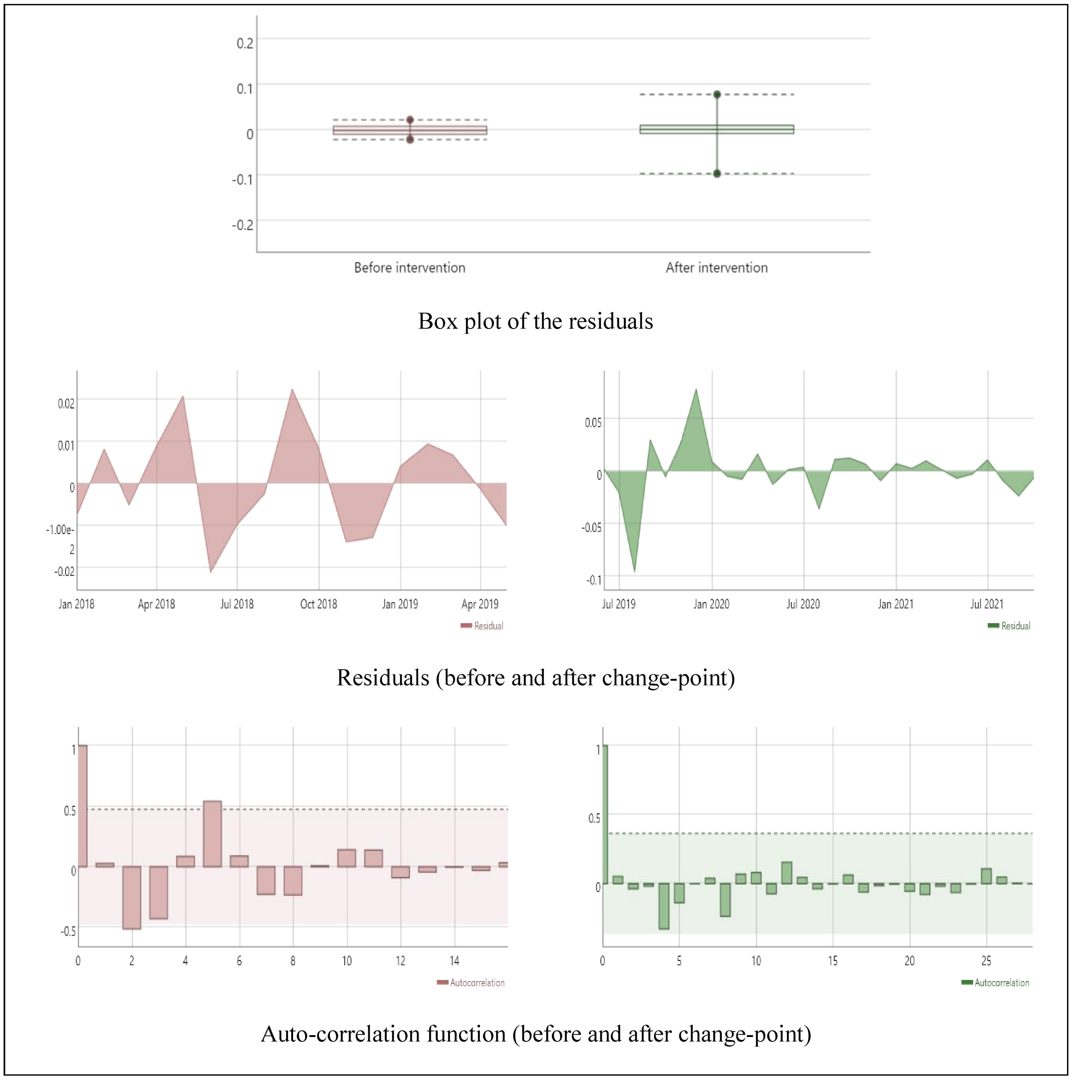
Residuals (before and after change-point)



Auto-correlation function (before and after change-point)

Plots 1: CEI mean in total institutions

Information Classification: General



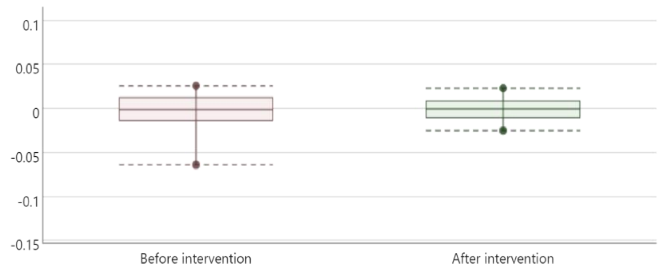
Box plot of the residuals

Residuals (before and after change-point)

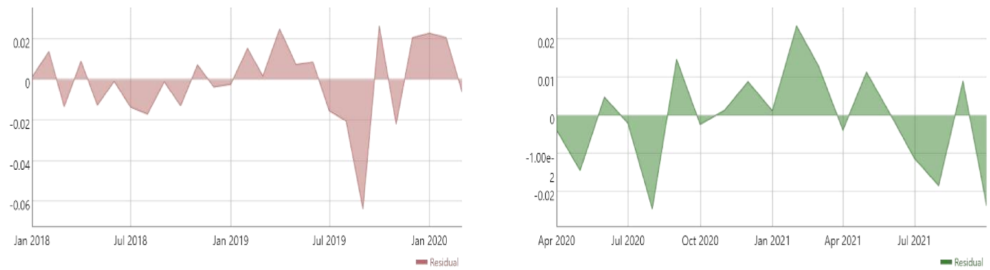
Auto-correlation function (before and after change-point)

Plots 2: CEI mean in tertiary institutions

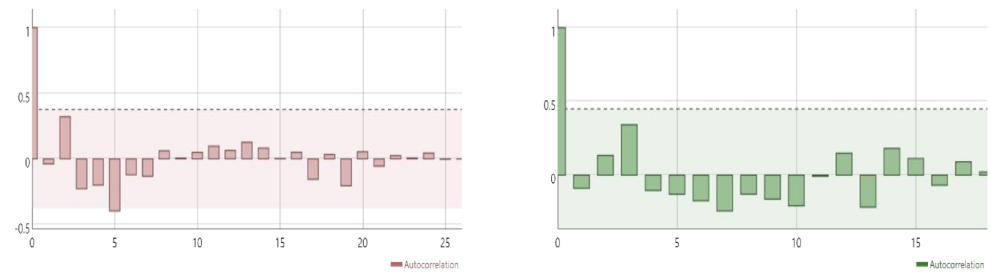
Information Classification: General



Box plot of the residuals



Residuals (before and after change-point)



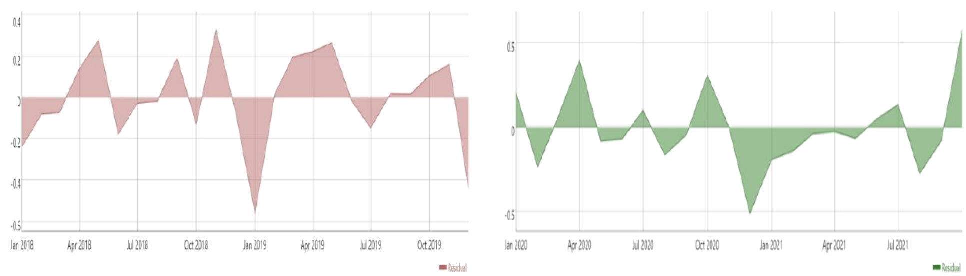
Auto-correlation function (before change-point)

Plots 3: CEI mean in secondary institutions

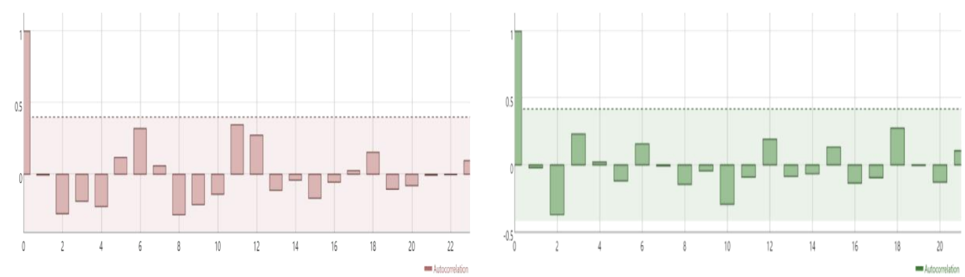
Information Classification: General

Appendix 4: Average length of stay (ALOS) mean

Box plot of the residuals



Residuals (before and after change-point)

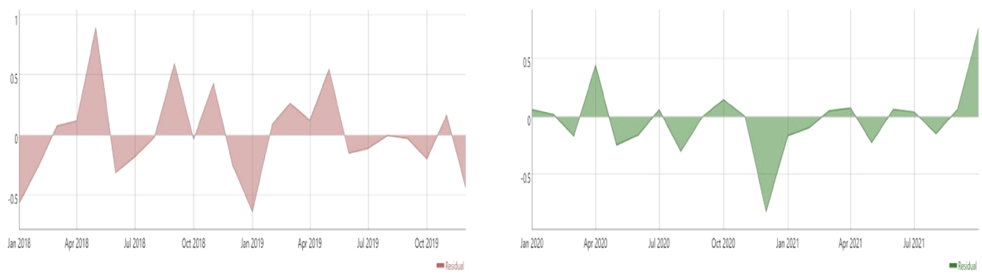


Auto-correlation function (before and after change-point)

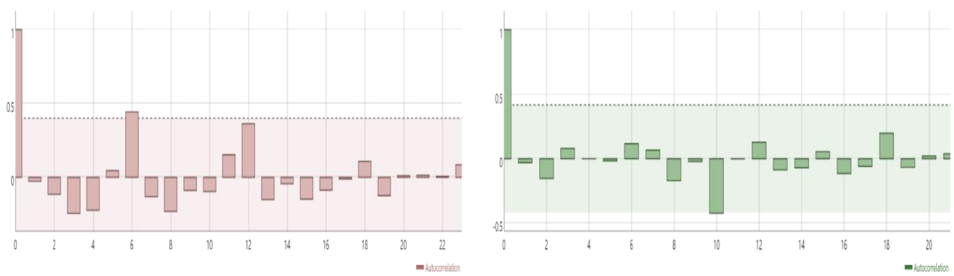
Plots 1: ALOS mean in total institutions

Information Classification: General

Box plot of the residuals



Residuals (before and after change-point)

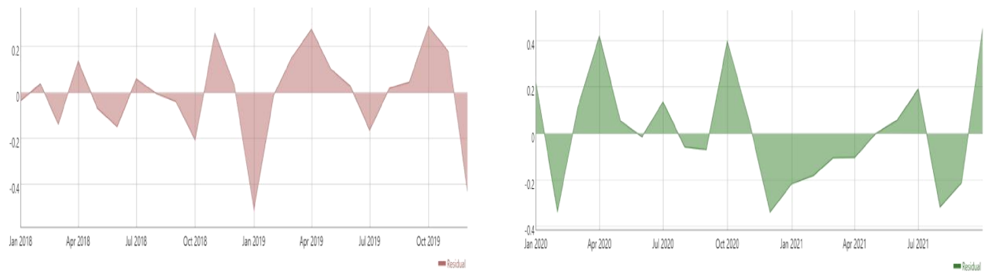


Auto-correlation function (before and after change-point)

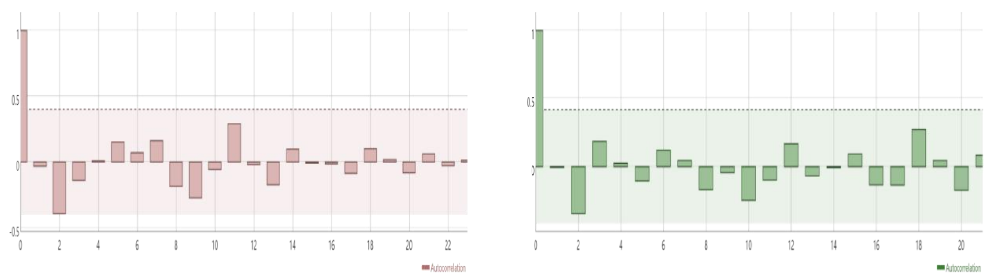
Plots 2: ALOS mean in tertiary institutions

Information Classification: General

Box plot of the residuals



Residuals (before and after change-point)

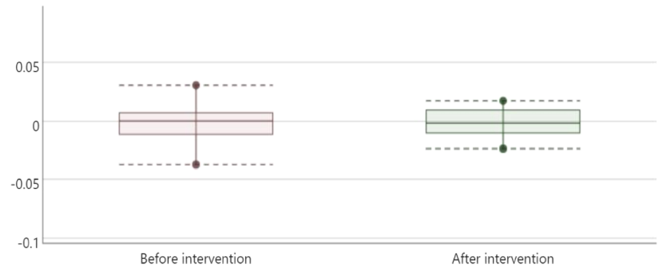


Auto-correlation function (before and after change-point)

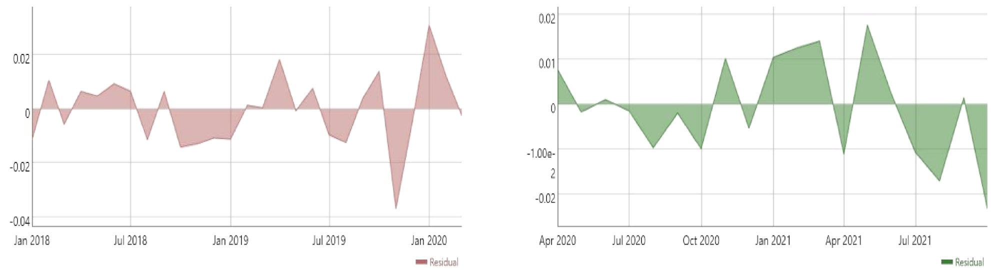
Plots 3: ALOS mean in secondary institutions

Information Classification: General

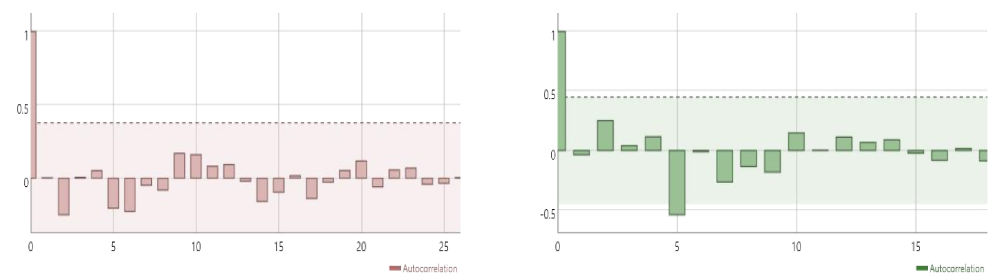
Appendix 5: Time efficiency index (TEI) mean



Box plot of the residuals



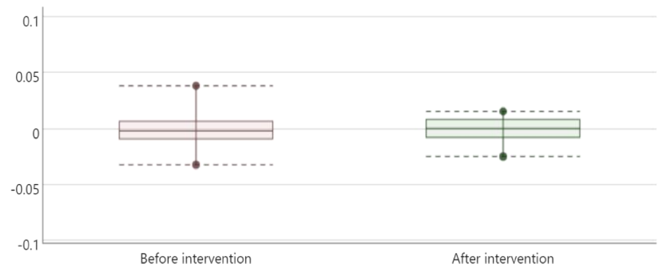
Residuals (before and after change-point)



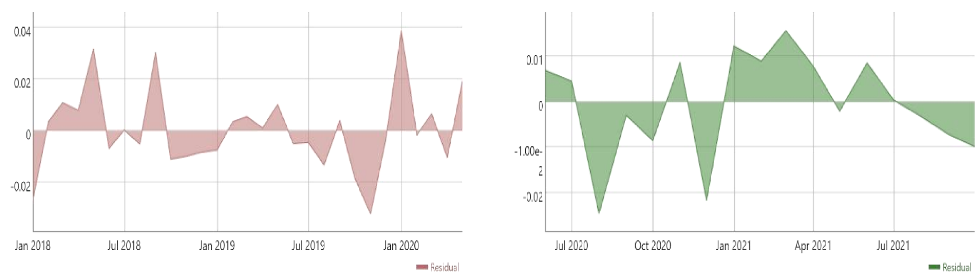
Auto-correlation function (before and after change-point)

Plots 1: TEI mean in total institutions

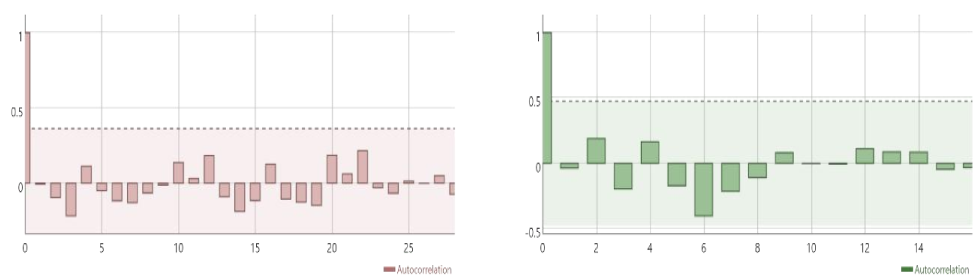
Information Classification: General



Box plot of the residuals



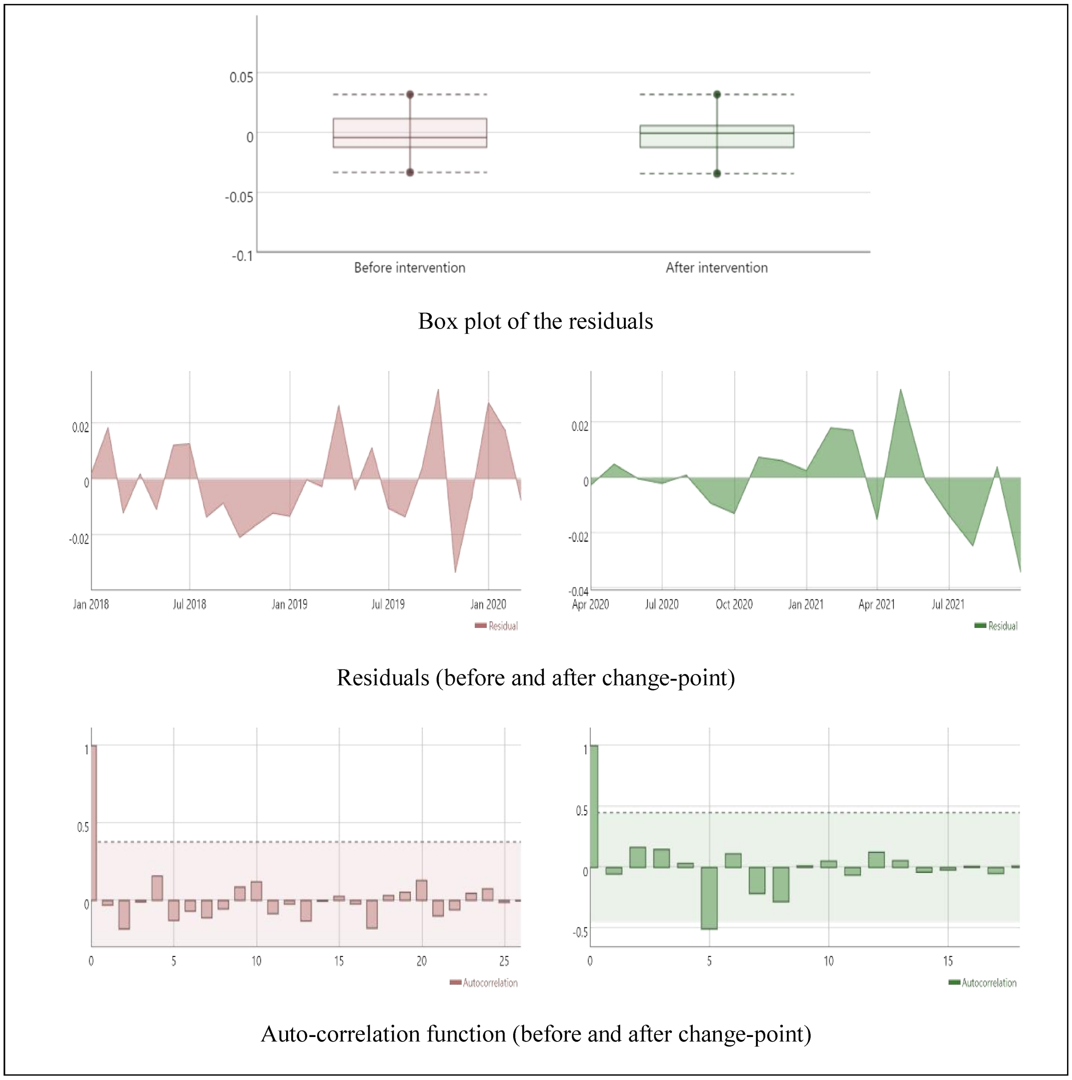
Residuals (before and after change-point)



Auto-correlation function (before and after change-point)

Plots 2: TEI mean in tertiary institutions

Information Classification: General



Box plot of the residuals

Residuals (before and after change-point)

Auto-correlation function (before and after change-point)

Plots 3: TEI mean in secondary institutions

Information Classification: General

Appendix A. The R-MITS model

Let y_{it} denote the outcome of interest for unit i at time t, with $i \in \{1,..., N\}$, $t \in \{1,...,n_i\}$, and n_i denoting the time series length for unit i. Then the general regression is defined as

$$y_{it} = \mu_{it} + \varepsilon_{it}$$

where μ_{it} is the mean function and ε_{it} is the stochastic process that model fluctuations around the mean functions and auto-correlation within the time series. The mean function of outcome is

$$\mu_{it} = \begin{cases} \beta_{i0}^{\tau} + \beta_{i1}^{\tau} t, & t < \tau \\ (\beta_{i0}^{\tau} + \delta_i^{\tau}) + (\beta_{i1}^{\tau} + \Delta_i^{\tau}) t, & t \geq \tau \end{cases}$$

where β_{i0}^{τ} denotes the intercept of the mean function prior to the change-point, β_{i1}^{τ} denotes the slope of the outcome prior to the change-point, $\beta_{i0}^{\tau} + \delta_i^{\tau}$ is the intercept of the post-intervention phase, $\beta_{i1}^{\tau} + \Delta_i^{\tau}$ is the slope of the post-intervention phase for the outcome in unit i, and τ denotes the global over-all-unit change-point of the response. In the case with only one unit, τ denotes the change-point for that one-time series. If $\delta_i^{\tau} + \Delta_i^{\tau} = 0$, then there is no change in the mean function of unit i before and after τ. Further model details about the estimation procedure of R-MITS are described in Cruz et al (2021) [37].

Appendix B. The stochastic component parameters of outcomes

Robust-ITS provides changes in the adjacent correlation (correlation between two consecutive time points) and variance of the response. Unit-specific estimates of the stochastic component parameters for every outcome are shown in Appendix Table 1.

As for all institutions, the adjacent correlation of CMI mean is larger and the standard deviation is smaller than before the policy was implemented; the same with the CEI mean performance. The adjacent correlation and standard deviation of the rest of the outcomes did not perform consistently well (either the adjacent correlation was small or the standard deviation was larger). It can be inferred that the change in CMI mean of the total public general hospitals may be more predictable and stable post-intervention, which are a positive result of the DRGs' policy intervention.

As can be seen in the subgroups, only the adjacent correlation of CMI mean in the secondary institutions is larger, and the standard deviation is smaller than before; only the adjacent correlation of CEI mean in the tertiary institutions is larger, and the standard deviation is smaller than before. The adjacent correlation and standard deviation of the rest of the outcomes did not perform well. It can be inferred that the change in CMI mean in secondary public general hospitals and the change in CEI mean of tertiary public general hospitals may be more predictable and stable post-intervention, which are positive results of the DRGs' policy intervention.

Appendix Table 1. Unit-specific estimates of the stochastic component parameters

Outcomes	Unit	Adjacent correlation			Standard deviation		
		Pre-change	Post-change	Change	Pre-change	Post-change	Change
CMI mean	Total institutions	0.2560	0.5109	↑	0.2139	0.2104	↓
	Tertiary institutions	0.5274	0.2934	↓	0.1859	0.2135	↑
	Secondary institutions	0.0718	0.3359	↑	0.2080	0.2071	↓
CPH mean	Total institutions	0.5988	0.0720	↓	0.1811	0.2700	↑
	Tertiary institutions	0.5246	0.3415	↓	0.1867	0.2683	↑
	Secondary institutions	0.4715	0.1647	↓	0.1734	0.2794	↑
CEI mean	Total institutions	0.0828	0.3093	↑	0.2302	0.1859	↓
	Tertiary institutions	0.0822	0.4342	↑	0.2534	0.1715	↓
	Secondary institutions	0.0986	0.4750	↑	0.1893	0.2293	↑
ALOS mean	Total institutions	−0.0453	−0.0369	↑	0.2302	0.2587	↑
	Tertiary institutions	0.0473	0.0535	↑	0.2140	0.2377	↑
	Secondary institutions	−0.1052	−0.2084	↓	0.2317	0.2296	↓
TEI mean	Total institutions	−0.1202	0.7081	↑	0.1920	0.2118	↑
	Tertiary institutions	0.1382	0.1259	↓	0.1911	0.2539	↑
	Secondary institutions	−0.2559	0.6688	↑	0.1840	0.2265	↑

Note: ALOS: average length of stay; CEI: cost efficiency index; CMI: case-mix index; CPH: cost per hospitalization; TEI: time efficiency index.