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ORIGINAL RESEARCH

Effects of a Diagnosis-Related Group Payment Reform on Length and Costs of Hospitalization in Sichuan, China: A Synthetic Control Study

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Background: Diagnosis-related group (DRG) payment policies are increasingly recognized as crucial instruments for addressing health care overprovision and escalating health care costs. The synthetic control method (SCM) has emerged as a robust tool for evaluating the efficacy of health policies worldwide.

Methods: This study focused on Panzhihua city in Sichuan Province, a pilot city for DRG payment reform implementation, serving as the treatment group. In contrast, 20 nonpilot cities within the province were utilized as potential control units. A counterfactual control group was constructed to evaluate the changes in average inpatient stay duration and health care organization costs following the DRG payment reform initiated in 2018.

Results: Focusing on Panzhihua, Sichuan Province, the analysis reveals that following the reform in March 2018, the average length of hospital stay in Panzhihua decreased by 1.35 days during 2019–2021. Additionally, the average cost per hospitalization dropped by 855.48 RMB, the average cost of medication per hospitalization decreased by 68.51 RMB, and the average cost of diagnostic and therapeutic procedures per hospitalization declined by 136.37 RMB. While global evidence backs DRGs for efficiency and cost reduction, challenges persist in addressing emerging issues like new conditions.

Conclusion: Since its introduction in 2018, the DRG payment reform in Sichuan Province has effectively reduced both the duration of hospital stays and the operational costs of health care facilities. However, potential drawbacks include compromised service quality and an elevated risk of patient readmission, indicating a need for further refinement in the implementation of DRG payment reforms in China.

Keywords: synthetic control method, health policy evaluation, diagnosis-related grouping, DRG, average hospitalization days, average hospital costs, China

Introduction

In 2020, global health spending soared to an unprecedented $9 trillion, equivalent to approximately 11% of the world's GDP,[1] driven significantly by the COVID-19 pandemic. Hospitalization, accounting for 40% of total government and social health care expenditures on average,[2] has become a central focus of health care policy reforms globally. In China, health expenditures reached RMB 8,532.749 billion in 2022, or 7.0% of GDP.[3,4] The cost per hospital stay was 11,673.70 yuan, with an average duration of 9.2 days.[5] These factors have significantly contributed to the rising total health expenditures. In response, the Chinese government has prioritized reforming hospital payment methods to reduce inpatient service costs and enhance hospital operational efficiency. These reforms aim to address the financial pressures from prolonged hospital stays and high hospitalization costs, which heavily impact overall health spending. By implementing more efficient payment systems and cost-control measures, the government seeks to curb rising health care costs, ensuring better resource allocation and sustainability within the health sector. This strategy not only aims to reduce the economic burden on the government and society but also to improve the quality and accessibility of health care for the population.[6]

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Historically, the fee-for-service (FFS) model has dominated hospital financing globally since the 1980s. This system incentivizes health care organizations to provide numerous itemized services, inadvertently increasing overall health care expenditures. In response, the diagnosis-related group (DRG) methodology was developed by Fetter in the United States in 1983[7] DRGs establish costs and categorize patients based on their diagnosis and additional characteristics such as age, gender, severity, and complications. Under the DRG system,[8,9] health care providers receive predetermined compensation per case, independent of actual treatment costs, aiming to streamline expenses by reducing hospitalization durations and costs[7,10].

The DRG payment policy has been adopted in various regions, including Japan,[11] the United States[12], and notably Germany in 2004, where it became the primary funding mechanism for all acute care hospitals[13,14]. China's engagement with DRG-based payment systems began late,[15,16] with pilot reforms initiated in 2011. A significant milestone was the inclusion of cities like Shenzhen in the 2017 DRG pilot reform. Despite these developments, the evaluation of DRG effectiveness, particularly at the provincial level in China, remains limited.

In March 2018, a major health care reform was launched in Panzhihua, Sichuan Province, implementing the DRG point-based medical insurance payment system. Recognized as the only city in Sichuan for this national pilot reform by the National Health Insurance Bureau in May 2019,[17] Panzhihua developed a localized DRG framework with hospital experts, addressing audit processes and complex case management. In August 2021, the Sichuan Provincial Health Insurance Bureau highlighted this model as exemplary and potentially scalable across China, following a positive evaluation by the National Payment Reform Pilot Research and Evaluation Group.[18] However, comprehensive research on the impact of DRG payment system implementation at the provincial level in China is lacking.

The Synthetic Control Method (SCM), proposed by Abadie and Gardeazabal in 2003,[19,20] is widely used for causal inference in panel data with a single treated unit.[21] SCM estimates policy effects by constructing counterfactual outcomes through a weighted combination of control units. The fundamental principle entails weighting control unit outcomes to construct the counterfactual outcome for the treated unit, assuming non-implementation of the health policy. Disparities in health policy outcomes between control and treated units are then evaluated. SCM's robustness and adaptability,[22] particularly in small sample sizes, make it valuable for policymakers seeking accurate intervention impact evaluations.[23]

This paper addresses the research gap by using the Synthetic Control Method (SCM) to evaluate the effectiveness of the DRG policy pilot initiated in Sichuan Province in March 2018. SCM creates a synthetic control region with similar economic and social characteristics to the policy area. The study focuses on Panzhihua, the only city in Sichuan piloting the DRG reform, assessing changes in average hospital stay length, hospitalization costs, medication costs, and diagnostic/therapeutic procedure costs.[24–27] Sichuan Province, with its dense population, developed economy, and advanced medical resources, is an ideal representative for DRG pilot programs in western China. Selecting Panzhihua City as a sample can effectively demonstrate the policy effects of DRG programs in over 30 cities, providing valuable insights for regions considering similar healthcare payment reforms.

Material and Methods

Study Design

Sichuan Province, located in southwestern China, borders Yunnan Province, Guizhou Province, and the Tibet Autonomous Region. In 2023, Sichuan's gross domestic product (GDP) ranked fifth among China's 31 provinces, amounting to 6,013.29 billion yuan.[28] The province has a well-developed industrial economy, with significant contributions from hydropower, liquor production, electronic equipment manufacturing, and oil and gas extraction, with a total industrial output exceeding 1.5 trillion yuan.[29] Sichuan also has a large and aging population, with 83.72 million people, of whom 14.168 million, or 16.93%, are aged 65 and above.[20]

Panzhihua City is situated in the southern part of Sichuan Province, on the south bank of the Jinsha River, strategically located at the transition zone between the Sichuan Basin and the Yunnan-Guizhou Plateau. In 2023, Panzhihua's GDP reached 130.380 billion yuan, placing it 15th among Sichuan's 21 cities. The city boasted 1059 healthcare institutions, with healthcare resources per 1000 population significantly higher than the provincial average: 9.15 beds, 3.61 physicians, and 4.70 registered nurses, compared to the provincial averages of 0.69 beds, 0.27 physicians, and 0.69 nurses, respectively.[30] In March 2018, Panzhihua became the first city in Sichuan to implement the reform of disease diagnosis-related groups (DRG) combined with the point method of cost payment under a total budget. By May 2019, it was selected as one of the 30 national pilot cities for DRG payment.

In this study, we employed a synthetic control methodology to evaluate the impact of the Diagnosis-Related Grouping (DRG) payment reform, implemented in March 2018 in Sichuan Province, China. We analyzed data from 21 cities in Sichuan Province, covering the period from 2012 to 2021 (Figure 1). Our analysis specifically focused on comparing Panzhihua, a city that has implemented DRG payment reforms for at least four years, with a "synthetic Panzhihua" constructed from multiple control cities that did not implement the reforms. This approach allowed us to estimate the reform's impact on several key healthcare metrics for local residents: average length of hospital Stay (Days), average cost per hospitalization (RMB), average cost of medication per hospitalization (RMB), average cost of diagnostic and therapeutic procedures per hospitalization (RMB), inpatient medication expense ratio (%) and inpatient diagnostic and therapeutic procedure expense ratio (%). The effectiveness of the pilot DRG reforms in Sichuan was assessed by quantifying their impact on these healthcare indicators for local residents.

Synthetic Control Method

In the study conducted in Panzhihua, a treatment unit, a "composite control" was constructed to replicate counterfactual results. This entailed selecting weights for the remaining 20 potential control units in Sichuan province, forming a linear combination of control results assuming the absence of reforms, as outlined by Kreif et al.[22]

Designating A_0 as the treatment unit (Panzhihua city, where the DRG payment method reform was implemented) and A_1 as the untreated unit (the other 20 cities in Sichuan province), the outcome vector $Y_j=\left(Y_{j1\ldots}Y_{jT0\ldots}Y_{jT}\right)$ for each local authority j was observed. Here, Y_{jt} denotes the outcome for the respective city area and time *t*.

The process of generating outcome data for each city$_j$ and time *t* can be expressed as follows, excluding the potential reform outcome Y^N_{jt} and the average treatment effect a_{jt}, such as: $Y_{jt}= Y^N_{jt}+a_{jt}D_{jt}$ and $Y_{jt}=\delta_t+\lambda_t\mu_j+0_tZ_j+\varepsilon_{jt}+a_{jt}D_{jt}$

Where:$\delta_t$represents a fixed effect for each year, Z_j is a coefficient with time-varying variables, 0_t is a vector of invariant predictions, and D_{jt} is an indicator of reform, taking the value of 1 if the reform implemented the reform and 0

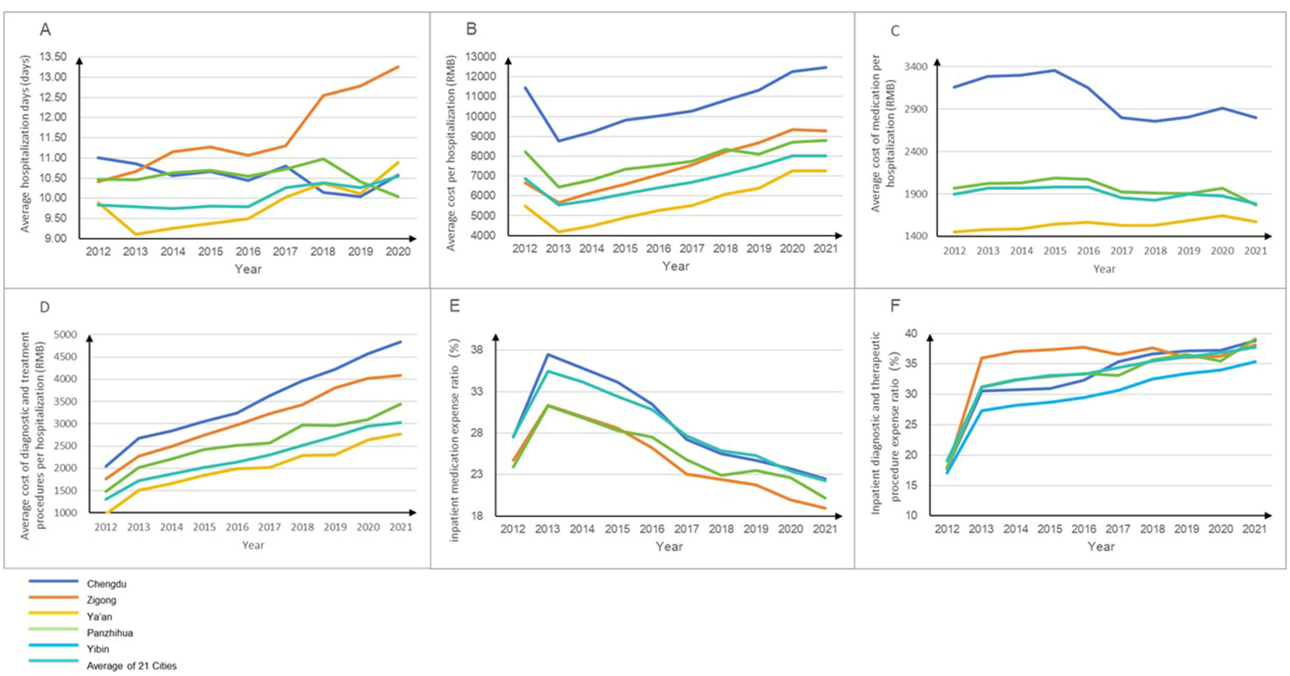

Figure 1 Trends in hospitalization metrics from 2012 to 2021 across Chengdu, Zigong, Panzhihua, Ya'an, and the provincial average (21 cities) in Sichuan Province, China. (**A–F**) represent the following parameters: "Average length of hospital stay (days)", "Average cost per hospitalization (RMB)", "Average cost of medication per hospitalization (RMB)", "Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)", "Inpatient medication expense ratio (%)" and "Inpatient diagnostic and therapeutic procedure expense ratio (%)" respectively.

otherwise. For the years 2012–2018 prior to policy implementation, there is no potential reform outcome Y_{jt}^{N} for either the experimental or control groups. The donor pool comprises 20 cities in Sichuan Province excluding Panzhihua.

The essence of the synthetic control method lies in estimating the unobserved counterfactual outcome Y_{jt}^{N} by selecting control group districts from the donor pool and fitting them to create a "synthetic control unit" that closely matches the characteristics of the treatment group. This is conducted through the estimation of weights associated with each control region *j*, which minimize the disparity between observed and unobserved confounders measured before the reform.

The minimization process aims to reduce the distance metric, employing a weighted sum: $W = (w_2, \ldots, w_{j+1})$: and $d = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)}$.

Here: X_0 is a K*1 measure of covariates including pre-reform outcomes and predictor variables for the treated region, X_1 is the equivalent control region matrix, and v is a K*K positive definite diagonal matrix assigning weights based on covariate importance and pre-intervention outcomes.

The effect of the reform, which can be evaluated in: $\hat{a}_{1t} = Y_{1t} - \hat{Y}_{1t}^{N}$. In the experimental group at each period after T_0 is determined by the difference between observed outcomes and their counterfactual counterparts, which are linearly combined from observed outcomes in potential control regions: $\hat{Y}_{1t}^{N} = \sum_{J=2}^{j+1} W_j Y_{jt}$.

Data Source

To ensure a robust analysis, our study utilized comprehensive datasets from authoritative sources. This study leveraged publicly accessible datasets provided by the Sichuan Provincial Government and its health administrations, encompassing data pertinent to 21 urban areas, as disseminated through the official portals of the Sichuan Provincial Bureau of Statistics (http://tjj.sc.gov.cn) and the Sichuan Provincial Health and Health Commission (https://wsjkw.sc.gov.cn/). Specifically, for the derivation of outcome variables such as average hospitalization days and average cost per hospitalization, in addition to their respective covariates, this study utilized data extracted from the Sichuan Health and Wellness Statistical Yearbook and the Sichuan Statistical Yearbook 2022 covering the period from 2012 to 2021.

Setting of Variables

To develop synthetic controls, our study incorporated variables identified in prior research as potential confounders influencing average hospitalization days and expenditure patterns.[24–27] These control variables were essential for a nuanced analysis and were streamlined into two categories relevant to the synthetic control method and the DRG payment reform context: demographic and socioeconomic variables, and health care resource variables. These variables, detailed in Table 1, guided the data collection for both outcome measures and control variables across 21 cities in Sichuan Province.

Informed by a comprehensive review of prior research, we developed six key outcome variables to assess the impact of the DRG payment reform. First, average length of hospital Stay (Days), which gauges the mean length of hospital stay per patient, was calculated. Prior studies suggest that a decrease in this measure is often indicative of enhanced health care efficiency, a potential effect of the DRG payment system. Second, the study assessed the average cost per hospitalization (RMB), the average cost of medication per hospitalization (RMB), the average cost of diagnostic and therapeutic procedures per hospitalization (RMB), the inpatient medication expense ratio (%), and the inpatient diagnostic and therapeutic procedure expense ratio (%). These measures were utilized to evaluate the impact of the DRG reform on cost control within healthcare organizations and the financial burden on patients during hospitalization. Specific definitions of the control and outcome variables included in the study are provided in the supplementary material, Table A1.

Statistical Analysis

In this study, we employed two methodological approaches: (1) a rudimentary comparative analysis of Six hospitalisation indicators across 21 cities in Sichuan Province, contrasting the periods before (prior to March 2018) and after (March 2018 to 2021) the intervention (Figure 1); (2) an advanced synthetic control method (SCM) analysis to assess the impact of the DRG payment reform intervention within a constructed synthetic Sichuan Province. The synthetic

Table 1 Control Variables and Outcome Variable

Category	No	Variables
Control Variables		
	X1	Number of resident population (10,000 people)
	X2	Urbanization rate (proportion of urban population) (%)
	X3	GDP per capita (yuan)
	X4	Annual hospitalizations per capita (times)
	X5	Number of health care institutions (units)
	X6	Number of beds per 1,000 population (beds)
	X7	Number of practicing physicians per 1000 population (persons)
	X8	Hospital bed occupancy rate (%)
Outcome Variables		
	Y1	Average length of hospital Stay (Days)
	Y2	Average cost per hospitalization (RMB)
	Y3	Average cost of medication per hospitalization (RMB)
	Y4	Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)
	Y5	Inpatient medication expense ratio (%)
	Y6	Inpatient diagnostic and therapeutic procedure expense ratio (%)

control group for Panzhihua city, Sichuan Province, was established using the synth2 command in STATA 16 (StataCorp LP, College Station, TX, USA), a tool developed by Professor Qiang Chen of Shandong University.[31] To validate the authenticity of the impact of the synthetic control, we executed spatial placebo tests along with leave-one-out (LOO) robustness assessments, thereby ensuring the scientific credibility of our findings.The synthetic control methodology utilized in this research is executed through Stata; refer to the supplementary materials' APPENDIX B for the implemented commands.

In-Space Placebo Tests

In synthetic control methods, in-space placebo testing involves the random reassignment of treated and untreated units within the sample. This study utilized the synth2 command in STATA 16 to conduct a spatial placebo test,[31] as detailed in the Supplementary Material. The test calculates the distribution of the test statistic by comparing the placebo effect in iterations where treatments are assigned to donor units, subsequently estimating the placebo effect. To ensure robustness, the mean squared prediction error (MSPE) of the dummy treatment unit, calculated as the pre-reform over post-reform MSPE, must not exceed twice that of the treatment unit. This criterion excludes units that are poorly fitted due to their limited informational value. The results from the synthetic control method, which remained consistent even after excluding such units, indicate that the observed effect of the reform is substantial and not attributable to spatial or geographical specificity.[21,32]

Leave-One-Out Robustness Test

In synthetic control experiments, there is a potential concern that the estimated treatment effect might be unduly influenced by a single control unit receiving disproportionate weighting. To address this issue, we utilized the leave-one-out (LOO) robustness test, as proposed by Abadie, Diamond, and Hainmueller.[21,32]. This method involves recalculating the original synthetic control model while systematically excluding each control unit one at a time. Such an approach allows for an assessment of the degree to which individual control units might disproportionately influence the results. For the estimates to be deemed robust, the outcomes and estimated treatment effects observed in the LOO synthetic control groups must align closely with those derived from the full synthetic control group, which incorporates all control units. This comparison ensures that the overall findings are not overly dependent on any single control unit, thereby enhancing the reliability and validity of the results of the synthetic control method.

Results

Temporal Trends in Hospitalization Metrics

The study opted to map cities that possessed synthetic weights exceeding 0, thereby ensuring the incorporation of outcome indicators in each synthetic control experiment. Figures 1A–F illustrate the trends from 2012 to 2021 in the average length of hospital stay (days), average cost per hospitalization (in RMB), average cost per hospitalization (RMB), average cost of diagnostic and therapeutic procedures per hospitalization (RMB), inpatient medication expense ratio (%), and inpatient diagnostic and therapeutic procedure expense ratio (%) across Chengdu, Zigong, Panzhihua, Ya'an, and the provincial average (21 cities) in Sichuan Province, China. All values are available in Table C1 to C6 of the supplementary materials.

Of particular note is the average length of hospital stay (days). In Figure 1A, it is observed that in Panzhihua city, from 2012 to 2017, this value increased from 10.47 days to 10.72 days, while the provincial average increased from 9.84 days to 10.27 days. Following the implementation of the DRG payment reform in Panzhihua city in March 2018, by 2021, this value decreased to 10.05 days, while the provincial average increased to 10.50 days. As depicted in Figure 1B, in 2012, the average cost per hospitalization in Panzhihua city was 8236.91 RMB, significantly higher than the provincial average of 6872.55 RMB. This cost sharply decreased to 6458.14 RMB in 2013 (compared to the provincial average of 5536.45 RMB) and gradually increased to 8787.79 RMB by 2021, approaching the provincial average of 8007.10 RMB. The trends in other indicators for Panzhihua city closely follow those of the provincial average, as shown in Figures 1C–E.

Pre-Reform Baseline City-Level Characteristics

Table 2 presents the control and outcome variables for Panzhihua and Synthetic Panzhihua before and after the reform implementation, along with the mean values for all cities in the donor pool. In general, Synthetic Panzhihua offers a more accurate match in terms of the hospitalization indicators' characteristics before the reform implementation compared to the mean values of the other cities, particularly in reflecting the alignment of all outcome variables in 2013, 2015, and 2017.

City Weights of Synthetic Panzhihua

Table 3 provides the weights assigned to each city in the synthetic Panzhihua among the urban areas in Sichuan province that served as donor pools. The highest weights were observed in the following variables: average length of hospital stay (days), average cost per hospitalization (RMB), and average cost of diagnostic and therapeutic procedures per hospitalization (RMB), where Chengdu, Zigong, and Ya'an had the highest weights.

In particular, the average cost of medication per hospitalization (RMB) showed significant synthesis primarily in Chengdu (0.283) and Ya'an (0.717). Regarding the inpatient medication expense ratio (%), the synthesis was predominantly observed in Chengdu (0.821) and Zigong (0.179). Furthermore, the inpatient diagnostic and therapeutic procedure expense ratio (%) was largely synthesized by Chengdu (0.318), Yibin (0.034), Ya'an (0.318), and Aba (0.162).

Synthetic Control Analysis: Panzhihua as a Case Study

Figure 2 delineates a discernible trend in the hospitalization indicator for Panzhihua in comparison to the synthetic Panzhihua counterpart. Notably, the implementation of reforms commencing in March 2018 has elicited pronounced differentials in the average Length of Hospital Stay (Days) between Panzhihua and the synthetic control group during the period of 2019–2021 (Figure 2A). Specifically, the average length for the reformed Panzhihua stood at 10.17 days, juxtaposed against 11.56 days for the synthetic control group, manifesting a disparity of 1.35days (refer to Table D1 in the Supplementary Materials).

Moreover, the average Cost per Hospitalization (RMB) has exhibited a gradual widening of the gap between Panzhihua and the synthetic control group over the aforementioned timeframe (Figure 2B). Notably, the average value for Panzhihua during 2019–2021 amounted to RMB 8528.02, contrasting with RMB 9383.50 for the synthetic control group, reflecting a divergence of 855.48 RMB (as detailed in Table D2 of the Supplementary Materials), thereby signifying the efficacy of the reform in mitigating the average cost of medication per hospitalization (RMB).

Table 2 City-Level Characteristics in Pre-Reform Period

Variables	Y1			Y2			Y3			Y4			Y5			Y6		
	Panzhihua	Synthesis	Average	Panzhihua	Synthesis	Average	Panzhihua	Synthesis	Average	Panzhihua	Synthesis	Average	Panzhihua	Synthesis	Average	Panzhihua	Synthesis	Average
X1	122.76	398.98	334.76	122.76	388.19	334.76	122.65	299.35	334.32	122.65	275.94	334.32	122.65	379.75	334.32	122.65	357.24	334.32
X2	66.23	56.32	44.49	66.23	55.77	44.49	67.21	56.02	45.92	67.21	54.12	45.92	67.21	55.71	45.92	67.21	55.17	45.92
X3	11.12	10.80	10.48	11.12	10.79	10.48	11.18	10.83	10.57	11.18	10.79	10.57	11.18	10.84	10.57	11.18	10.84	10.57
X4	1.26	1.23	1.19	1.26	1.23	1.19	1.28	1.24	1.20	1.28	1.24	1.20	1.28	1.24	1.20	1.28	1.22	1.20
X5	6.96	8.05	8.17	6.96	8.03	8.17	6.97	7.84	8.18	6.97	7.76	8.18	6.97	8.00	8.18	6.97	8.13	0.18
X6	8.24	7.54	6.16	8.24	7.48	6.16	8.39	8.30	6.58	8.39	8.08	6.58	8.39	7.59	6.58	8.39	7.58	6.58
X7	18.63	11.07	5.73	18.63	10.66	5.73	19.99	12.47	6.10	19.99	10.76	6.10	19.99	9.90	6.10	19.99	11.13	6.10
X8	99.65	91.74	87.91	99.65	92.56	87.91	96.57	84.00	86.41	96.57	87.89	86.41	96.57	96.83	86.41	96.57	82.16	86.41
Y*(2013)	10.45	10.29	9.76	6458.14	6157.70	5490.37	2021.02	1992.13	1961.51	2016.90	1921.70	1711.84	31.29	32.45	36.08	31.23	32.05	31.35
Y*(2015)	10.69	10.56	9.75	7362.37	7081.08	6045.22	2087.11	2058.82	1977.43	2425.14	2298.74	2000.32	28.35	29.58	32.88	32.94	32.49	33.00
Y*(2017)	10.72	10.80	10.25	7756.04	7813.55	6641.23	1923.95	1890.18	1849.82	2565.18	2628.77	2288.59	24.81	23.84	28.10	33.07	34.21	34.24

Notes: X1 represents number of resident population (10,000 people), X2 represents urbanization rate (proportion of urban population) (%), X3 represents GDP per capita (RMB), X4 represents annual hospitalizations per capita (times), X5 represents number of health care institutions (units), X6 represents number of beds per 1000 population (beds), X7 represents number of practicing physicians per 1000 population (persons), X8 represents hospital bed occupancy rate (%); Y1 represents average length of hospital stay (days), Y2 represents average cost per hospitalization (RMB), Y3 represents average cost of medication per hospitalization (RMB), Y4 represents average cost of diagnostic and therapeutic procedures per hospitalization (RMB), Y5 represents inpatient medication expense ratio (%), Y6 represents inpatient diagnostic and therapeutic procedure expense ratio (%).

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Table 3 City-Level Characteristics in Pre-Reform Period

City	Weight (y1)	Weight (y2)	Weight (y3)	Weight (y4)	Weight (y5)	Weight (y6)
Chengdu	0.303	0.276	0.283	0.185	0.821	0.318
Zigong	0.419	0.481	≈0	0.260	0.179	≈0
Luzhou	≈0	≈0	≈0	≈0	≈0	≈0
Deyang	≈0	≈0	≈0	≈0	≈0	≈0
Mianyang	≈0	≈0	≈0	≈0	≈0	≈0
Guangyuan	≈0	≈0	≈0	≈0	≈0	≈0
Suining	≈0	≈0	≈0	≈0	≈0	≈0
Neijiang	≈0	≈0	≈0	≈0	≈0	≈0
Leshan	≈0	≈0	≈0	≈0	≈0	≈0
Nanchong	≈0	≈0	≈0	≈0	≈0	≈0
Meishan	≈0	≈0	≈0	≈0	≈0	≈0
Yibin	≈0	≈0	≈0	≈0	≈0	0.034
Guangan	≈0	≈0	≈0	≈0	≈0	≈0
Dazhou	≈0	≈0	≈0	≈0	≈0	≈0
Ya'an	0.278	0.243	0.717	0.555	≈0	0.318
Bazhong	≈0	≈0	≈0	≈0	≈0	≈0
Ziyang	≈0	≈0	≈0	≈0	≈0	≈0
Aba	≈0	≈0	≈0	≈0	≈0	0.162
Ganzi	≈0	≈0	≈0	≈0	≈0	≈0
Liangshan	≈0	≈0	≈0	≈0	≈0	≈0

It merits attention that antecedent to the implementation of the reform in March 2018, the average cost of medication per hospitalization (RMB) in Panzhihua eclipsed that of the synthetic control group (Figure 2C). However, subsequent to the reform in 2019, the average value for Panzhihua descended below that of the synthetic control group (1880.38 RMB vs 1948.88 RMB), with specific numerical values delineated in Table D3 of the Supplementary Materials.

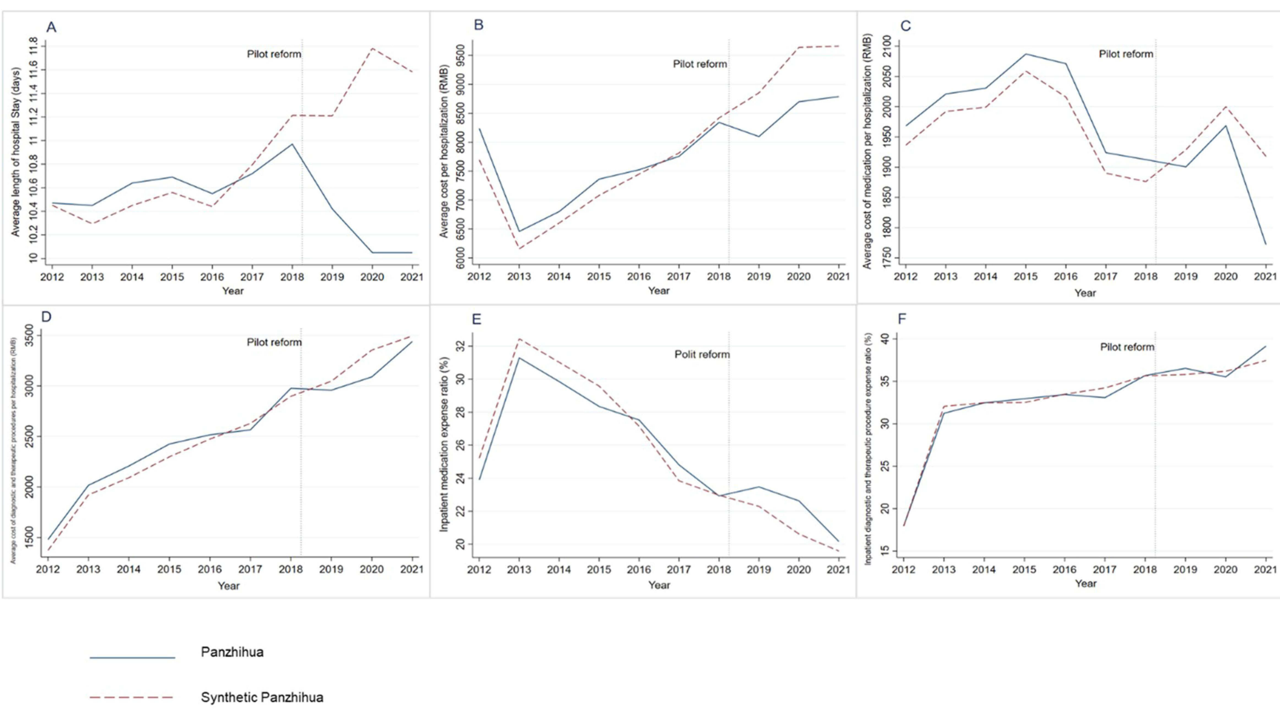

Figure 2 Graphical Results of the Comprehensive Control Method for Hospitalization Indicators. (**A**–**F**) respectively represent the following parameters: "Average length of hospital stay (days)", "Average cost per hospitalization (RMB)", "Average cost of medication per hospitalization (RMB)", "Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)", "Inpatient medication expense ratio (%)" and "Inpatient diagnostic and therapeutic procedure expense ratio (%)" respectively.

Further analysis reveals that the average cost of diagnostic and therapeutic procedures per hospitalization (RMB) in Panzhihua during 2019–2021 was tabulated at 3162.00 RMB, registering a decrement in contrast to the synthetic control group's average of 3298.37 RMB, amounting to a reduction of 136.37 RMB (as explicated in Table D4 in the Supplementary Materials; Figure 2D).

Additionally, the differential between the inpatient medication expense ratio (%) and inpatient diagnostic and therapeutic procedure expense ratio (%) in Panzhihua City exhibited diminution in both pre- and post-implementation periods of the reform, with specific variations delineated in the table contained within the Supplementary Material (refer to Table D4).

Treatment Effect of DRG Payment Reform

Figure 3 delineates the Treatment Effect of Panzhihua's DRG Payment Reform, delineating the disparities between hospitalization-related indicators in Panzhihua and a synthetic control group before and after the reform. Preceding Panzhihua's reform in March 2018, (Figure 3A) the average length of hospital stay (days), (Figure 3B) the average cost per hospitalization (RMB), (Figure 3C) the average cost of medication per hospitalization (RMB), and (Figure 3D) the average cost of diagnostic and therapeutic procedures per hospitalization (RMB) exhibited a propensity towards decrease. However, subsequent to the reform, a notable downward trajectory is observed in these four indicators, particularly during the period spanning March 2018 to 2020.

Conversely, (Figure 3E) the inpatient medication expense ratio (%) and (Figure 3F) the inpatient diagnostic and therapeutic procedure expense ratio (%) displayed a somewhat ascending trend prior to the reform. Following the reform, while a decline is discernible, the overall trend suggests a more pronounced upward movement. Specifically, in 2020, the disparity between Panzhihua and its synthetic counterpart in the inpatient medication expense ratio (%) stands at 2.01%, with an average disparity of 1.26% observed during the years 2019–2021. Meanwhile, Panzhihua's inpatient diagnostic and therapeutic procedure expense ratio (%) notably exceeds that of the synthetic Panzhihua (39.14% vs 37.45%), representing a gap of 1.69%. However, this gap regresses to 0.58% in the interim period of mid-2019 to 2021.

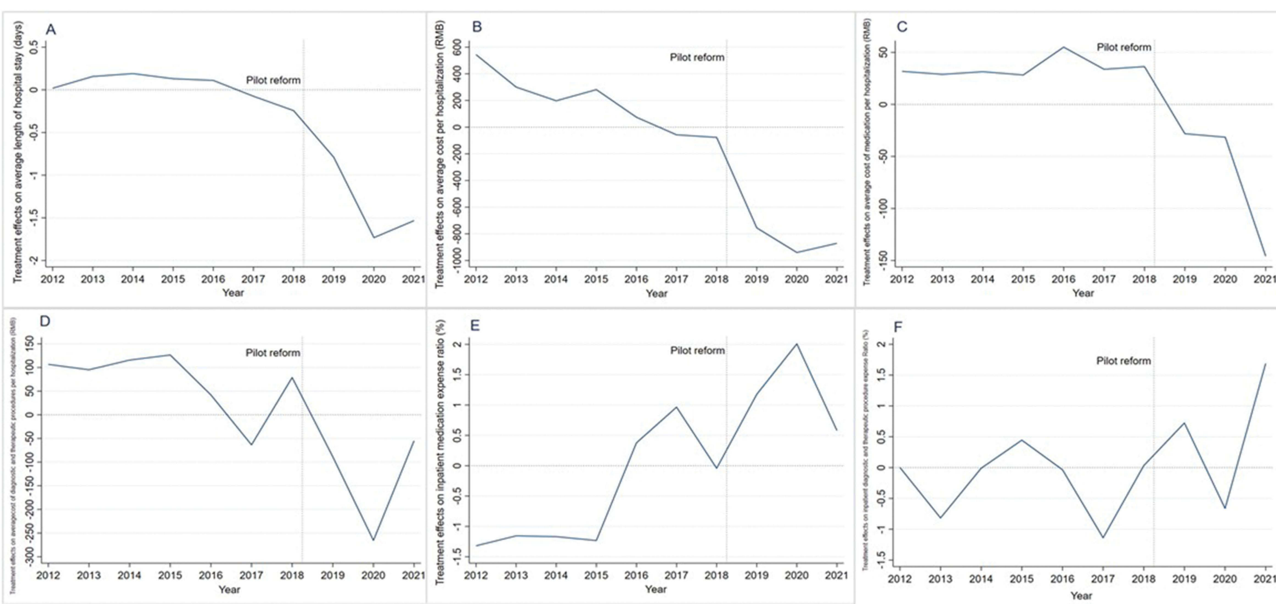

Figure 3 Treatment effects for hospitalization metrics.(**A–F**) respectively represent the the Reform's Treatment on these metrics: "Average length of hospital stay (days)", "Average cost per hospitalization (RMB)", "Average cost of medication per hospitalization (RMB)", "Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)", "Inpatient medication expense ratio (%)" and "Inpatient diagnostic and therapeutic procedure expense ratio (%)" respectively.

Validity Checks: Placebo and Robustness Tests

In-Space Placebo Testing

We conducted a spatial placebo test to exclude cities where the pre-reform to post-reform root mean square prediction errors (RMSPEs) exceeded twice that of Panzhihua. Figure 4 presents the results of this spatial placebo effect. Notably, both Figure 4E and the corresponding subfigures demonstrate the impact on various healthcare metrics in Panzhihua post-March 2018 reform, following the exclusion of certain cities. Specifically, the average length of hospital stay (days) (Figure 4A), the average cost per hospitalization (RMB) (Figure 4B), the average cost of medication per hospitalization (RMB) (Figure 4C), and the average cost of diagnostic and treatment procedures per hospitalization (RMB) (Figure 4D) all exhibit a declining trend. These findings underscore that the observed effects are attributable to the reform rather than regional variability, thereby reinforcing the robustness of the reform's impact.

Robustness Testing

The study employs the Leave-One-Out (LOO) robustness check. Typically, the optimal synthetic control is a weighted average of a small number of donor units, as most control units have zero weights. If the results of the LOO synthetic control and the treatment effect are similar to those obtained with the synthetic control using all control units, the estimates are considered robust. The LOO analysis involves re-estimating the synthetic control effect by omitting one donor unit from the donor pool in each iteration. This analysis assesses the extent to which the results are driven by any specific control unit. Figure 5A–F demonstrate that the LOO synthetic control results and treatment effects in this study are similar to those of the synthetic control using all control units, indicating that the estimates are relatively robust. The complete results of the robustness test can be found in Table E1 to E6 in the supplementary materials.

Discussion

This study represents the first controlled trial utilizing Synthetic Control Method (SCM) to assess the effects of the DRG Medicare payment pilot reform in China. Focusing on Panzhihua, Sichuan Province, the analysis reveals that following

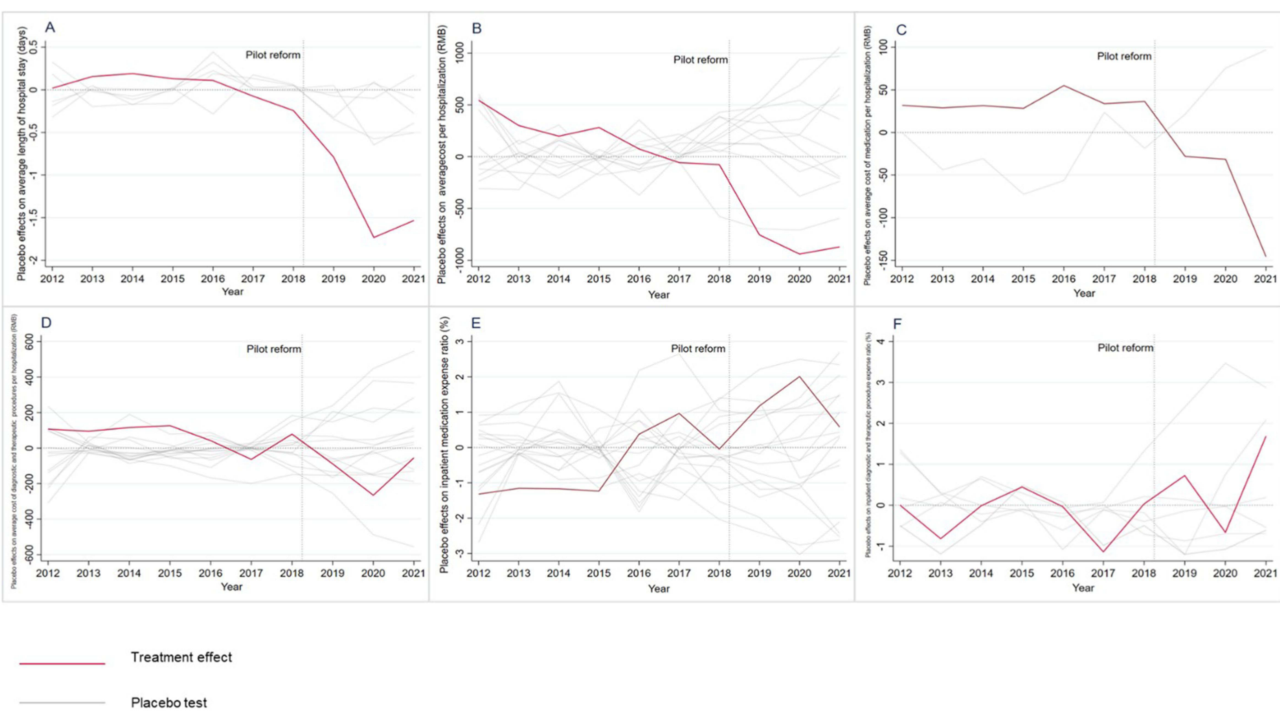

Figure 4 In-space Placebo Test Results for Panzhihua Hospitalization metrics. (**A**–**F**) respectively represent the the Reform's in-space placebo tests of these metrics: "Average length of hospital stay (days)", "Average cost per hospitalization (RMB)", "Average cost of medication per hospitalization (RMB)", "Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)", "Inpatient medication expense ratio (%)" and "Inpatient diagnostic and therapeutic procedure expense ratio (%)" respectively.

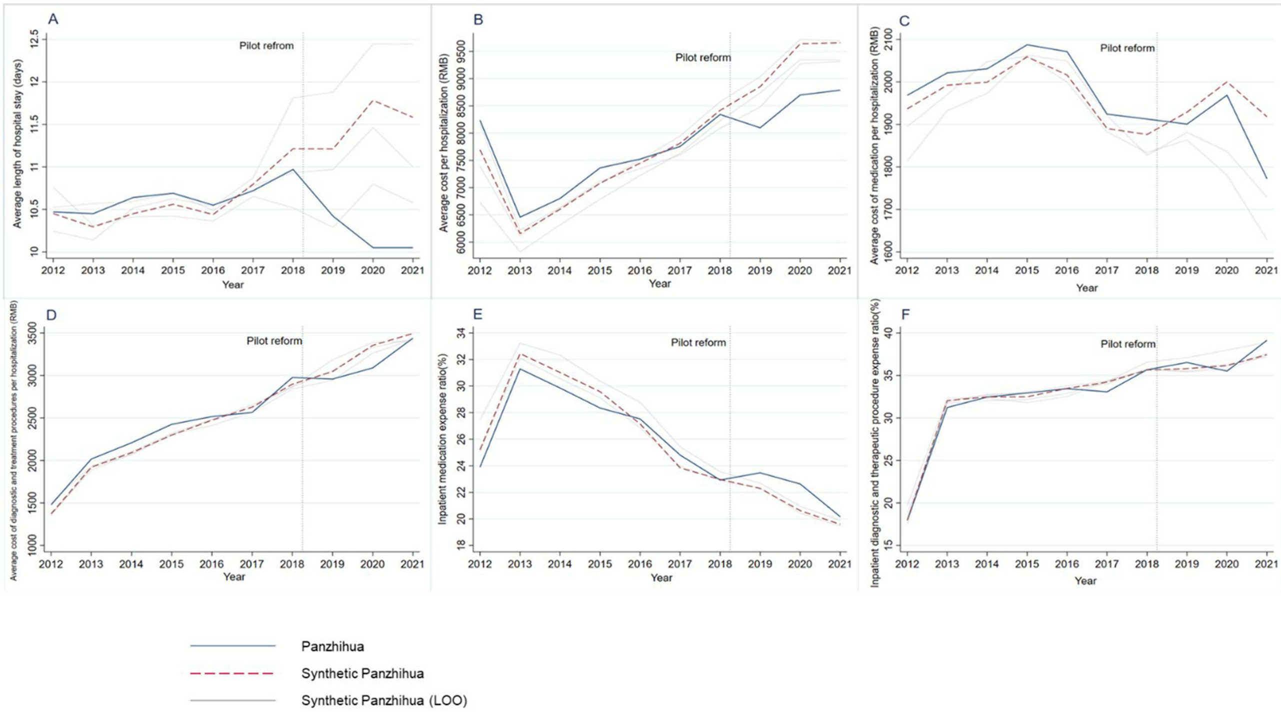

Figure 5 Leave-One-Out robust tests of DRG payment reform outcomes. (**A**–**F**) respectively represent the the LOO robust tests of these metrics: "Average length of hospital stay (days)", "Average cost per hospitalization (RMB)", "Average cost of medication per hospitalization (RMB)", "Average cost of diagnostic and therapeutic procedures per hospitalization (RMB)", "Inpatient medication expense ratio (%)" and "Inpatient diagnostic and therapeutic procedure expense ratio (%)" respectively.

the reform in March 2018, the average length of hospital stay in Panzhihua decreased by 1.35 days during 2019–2021. Additionally, the average cost per hospitalization dropped by 855.48 RMB, the average cost of medication per hospitalization decreased by 68.51 RMB, and the average cost of diagnostic and therapeutic procedures per hospitalization declined by 136.37 RMB. These significant reductions in both patient days and hospitalization costs are corroborated by spatial placebo tests and Leave-One-Out (LOO) robustness checks.

Impact of DRG Reforms on Efficiency and Quality of Inpatient Services

Similar to numerous studies, our research found that DRG reforms effectively enhance regional inpatient service capacity and efficiency,[33,34] particularly by reducing the average patient length of stay compared to traditional Fee-For-Service (FFS) Medicare payment methods. For instance, a study at the People's Hospital of Peking University in China revealed that after piloting DRG reform in Beijing, the average patient length of stay decreased from 10.08 days in 2010 to 7.47 days.[34] Similarly, the Austrian DRG system reduced the average length of stay (ALOS) from 8.3 days in 1997 to 6.8 days in 2007.[35] Conversely, the introduction of DRG reforms in Germany led to a reduction in the average hospitalization days per case for hand surgery patients,[36] but it also increased the average cost of hospitalization per day.

Moreover, DRG reforms may impact the quality of inpatient services. In Hong Kong, the implementation of a DRG program was associated with improved inpatient service quality. During the implementation period (April 2009 to March 2012), there was a 4.12% (95% CI, 1.89%-6.35%) reduction in inpatient mortality and a 2.37% (95% CI, 1.28%-3.46%) reduction in emergency readmission rates,[37] compared to the pre-implementation period. However, some studies have shown that DRGs can lead to increased readmission rates and potentially adverse impacts on patient prognosis, particularly among older adults or vulnerable populations with complex health conditions.[38] For instance, Luo et al reported an increase in 30-day readmission rates following DRG implementation in Panzhihua City, especially among older adults and surgical patients.[25]

The experiences of France and Switzerland underscore the importance of balancing efficiency improvements with the quality of care when implementing DRG reforms for chronic health conditions [35,36]. Additionally, in Chinese pilot cities, where there is a tendency for high coding of the lowest codes, it is crucial to focus on fine-tuning disease diagnoses and differentiating disease examination and treatment during DRG implementation. Continuous efforts to enhance the quality of inpatient service provision are essential.

The Impact of DRG Payment Reform on Patient Hospitalization Costs

DRG payment systems have been demonstrated to effectively control operating costs in[25] China.[8,9] For example, hospitalizations for patients with COPD, AMI, and CI were reduced by RMB 11,094, RMB 4833, and RMB 4987, respectively,[25] in a Chinese city, with similar cost reductions observed in New Jersey, USA.[39]

The primary mechanism by which DRG payments reduce total inpatient costs is through minimizing unnecessary medications, tests, and treatment procedures, such as reducing antimicrobial prescriptions and C-section rates. A study conducted in Zhongshan City on patients diagnosed with acute myocardial infarction (AMI) found that the use of percutaneous coronary intervention (PCI) among Medicare patients decreased significantly by 4.55% following the reform.[40] This reduction contributed to a significant decrease in total hospital costs by $986.10 post-reform.

However, the impact of DRG payments on healthcare costs is not uniformly positive. A study examining post-reform hospital expenses in rural areas of Shandong, Guangdong, and Shaanxi in China revealed that both medical insurance fund expenditures (3856.32 yuan vs 3254.03 yuan) and out-of-pocket expenses (5759.62 yuan vs 5534.00 yuan) increased compared to the pre-reform period.[41] This increase in costs can be attributed to the lack of advanced patient health information management systems and regulatory mechanisms for inpatient service delivery. Consequently, in low- and middle-income countries, DRG payments may inadvertently raise healthcare costs and financial burdens on health systems and rural patients.

The Impact of Unaccounted Observational Variables on Research Outcomes

Due to the limitations in the control variables included in the synthetic control method, it is not possible to exhaustively capture all the characteristics of the synthetic Panzhihua. Consequently, there may be unaccounted-for variables that affect the outcome variables. Notably, the period from 2019 to 2021 coincides with the outbreak of the COVID-19 pandemic. The occurrence of COVID-19 could have led to a reduction in the average length of hospital stays for surgical patients in China,[41] while simultaneously increasing the average length of hospital stays for patients with respiratory diseases and COVID-19 patients with comorbidities. For instance, the median hospitalization time for COVID-19 patients in Sichuan Province was 19 days, with longer durations observed for elderly patients, those admitted to provincial hospitals, and critically ill patients.[42]

A study conducted in Shandong Province, China, found that the total average cost of COVID-19 treatment was $6827 per treatment, with drug acquisition accounting for 45.1% of the total cost.[43] The presence of comorbidities in COVID-19 patients could lead to increased drug and hospitalization costs, which may, in turn, interfere with the outcome indicators comparing synthetic Panzhihua and actual Panzhihua. This interference could manifest in variations in patient drug expenses and costs related to treatment and diagnostics.

Furthermore, in February 2020, Sichuan Province implemented a province-wide policy for centralized procurement of drugs and medical devices. This policy may have led to a reduction in hospitalization costs for drugs and devices for common diseases, which could also confound the effects of the Diagnosis-Related Group (DRG) reform on cost-related outcome indicators.

Suggestions

To effectively scale up policies in less developed areas, it is crucial to implement changes gradually, utilizing hospitals and model districts to pilot the rollout of Diagnosis-Related Groups (DRGs).[7] For instance, China began its DRG payment reforms in 2019 and expanded these reforms by establishing 30 DRG reform cities in 2021.[18] This pilot-based approach has facilitated policy development and refinement at both provincial and national levels. By incorporating new evidence and insights from local practices, these reforms have been adapted to fit local contexts, ensuring the policies are replicable and context-sensitive.[15] Lessons can be drawn from Korea and Japan,[11] where the establishment of appropriate infrastructure, human resource capacity, and information management systems were prerequisites for the phased implementation of DRGs. In these countries, DRG management was introduced in various hospitals under different circumstances, highlighting the importance of a tailored approach.

Policymakers should also focus on refining the design of each component of DRG payments. While DRG payment reforms can potentially enhance efficiency, they may also compromise equity and the quality of healthcare by reducing the average length of stay and affecting service quality, particularly for patients with complex medical conditions. Therefore, in low- and middle-income areas, it is essential to base policy development on robust clinical outcome evidence and comparative research.[7] Additionally, policies must ensure the standardization of coding and data availability to prevent discrepancies, such as diseases with high DRGs but low codes, or vice versa.

Moreover, developed countries can learn from the experiences of balancing efficiency and quality through reforms and optimizing the combination of DRG payments with other payment mechanisms. For example, Denmark began replacing DRGs with value-based payments in 2019.[44] In England, a hybrid payment approach has been adopted post-2019, which includes fixed payments, variable components based primarily on DRGs, and quality-related components.[45] Similarly, France aims to reduce the proportion of DRG payments from 80% to 50%.[46] These examples illustrate the potential for achieving an optimal balance between efficiency and quality in healthcare payment reforms.

Limitations

The study, which analyzed the duration of the Panzhihua DRGs health insurance payment reform from 2019 to 2021, is insufficient to draw definitive conclusions. Future research should consider extending the study period, especially as the ongoing normalization of the COVID-19 pandemic might diminish its impact.

Geographically, the study is limited to the pilot reform in Panzhihua City, Sichuan Province, China. While this has relevance for developing countries and less developed regions, future research should expand the geographical scope to include regions with varying levels of economic development to better understand the reform's effects.

The observed reduction in hospitalization and drug costs may be influenced by concurrent reforms in drug and medical service pricing and centralized drug purchasing policies in China's urban public hospitals.[47] Future research should explore the interaction between DRGs and these reforms.

Additionally, the study only includes control variables commonly used in existing literature, which may not account for all potential confounding factors. Future scholars should consider incorporating a broader range of variables to provide a more comprehensive analysis.

Conclusion

This pioneering study, utilizing the Synthetic Control Method, investigated the effects of DRG Medicare payment reform in China, specifically in Panzhihua, Sichuan Province. It revealed significant reductions in hospital stay duration and associated costs, particularly in drug and treatment expenses, following the reform. These insights emphasize the importance of a gradual, pilot-based approach to DRG implementation in developing countries, drawing from developed countries' experiences to ensure efficiency and cost-effectiveness in healthcare reforms. These findings align with similar observations in other regions, suggesting enhanced inpatient service efficiency and cost reduction due to DRG reforms. Future research should broaden its temporal and geographical scope for a more comprehensive analysis. Additionally, exploring the interplay between DRG reforms and concurrent policies, such as drug pricing reforms, is crucial. Incorporating a wider array of control variables in future analyses would further strengthen the validity of findings.

Abbreviations

GDP: Gross Domestic Product; FFS: Fee-for-Service; DRG: Diagnosis-Related Group; SCM: Synthetic Control Method; LOO: Leave-One-Out; MSPE: Mean Squared Prediction Error.

Data Sharing Statement

The datasets used and analyzed during this study are publicly accessible through the official portals of the Sichuan Provincial Bureau of Statistics (http://tjj.sc.gov.cn) and the Sichuan Provincial Health and Health Commission (https://wsjkw.sc.gov.cn/). Additionally, these datasets, including data from the Sichuan Health and Wellness Statistical Yearbook and the Sichuan Statistical Yearbook 2022, can be obtained from the corresponding author upon reasonable request.

Ethics Approval and Informed Consent

The study was approved by the Ethics Committee of Huazhong University of Science and Technology.

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Disclosure

The authors report no conflicts of interest in this work.

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