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ORIGINAL RESEARCH

Impact of Medical–Pharmaceutical Separation Reform on Hospitalization Expenditure in Tertiary Public Hospitals: Difference-in-Difference Analysis Based on Panel Data from Beijing

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Purpose: The medical–pharmaceutical separation (MPS) reform is a healthcare reform that focuses on reducing the proportion of drug expenditure. This study aims to analyze the impact of the MPS reform on hospitalization expenditure and its structure in tertiary public hospitals.

Methods: Using propensity score matching and multi-period difference-in-difference methods to analyze the impact of the MPS reform on hospitalization expenditure and its structure, a difference-in-difference-in-difference model was established to analyze the heterogeneity of whether the tertiary public hospital was a diagnosis-related-group (DRG) payment hospital. Of 22 municipal public hospitals offering tertiary care in Beijing, monthly panel data of 18 hospitals from July 2011 to March 2017, totaling 1242 items, were included in this study.

Results: After the MPS reform, the average drug expenditure, average Western drug expenditure, and average Chinese drug expenditures per hospitalization decreased by 24.5%, 24.6%, and 24.1%, respectively ($P < 0.001$). The proportions of drug expenditure decreased by 4.5% ($P < 0.001$), and the proportion of medical consumables expenditure increased significantly by 2.7% ($P < 0.001$).

Conclusion: The MPS reform may significantly optimize the hospitalization expenditure structure and control irrational increases in expenditure. DRG payment can control the tendency to increase the proportions of medical consumables expenditure after the reform and optimize the effect of the reform. There is a need to strengthen the management of medical consumables in the future, promote the MPS reform and DRG payment linkage, and improve supporting measures to ensure the long-term effect of the reform.

Keywords: diagnosis-related-group, provider payment reforms, healthcare expenditure, propensity-score-matching, difference-in-difference-in-difference, China

Introduction

In most developed countries, drug expenditure generally comprises no more than 25% of the total medical expenditure, with the proportion being no more than 30% in Southeast Asian countries. However, in 2015, the proportion was as high as 31.34% in China.[1] The primary reason for this high proportion is that, at the time of the founding of New China, financial resources were insufficient to subsidize hospital income. For sustainable development of hospitals, medical institutions were allowed to mark up the prices of drugs by no more than 15%. Subsequently, drug income became the main source of medical income.[2] A high proportion of drug expenditure in total medical expenditure carries the potential risk of irrational medicine use, affecting patients' health.[3] Moreover, the excessively high drug expenditure brings a heavy economic burden to patients.[4–8]

To improve this situation, since the proposed implementation of the medical–pharmaceutical separation (MPS) reform in 2009, a realistic method to abolish drug markups in public hospitals has been explored across the country.[9] In 2012,

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the Beijing Municipality began implementing the MPS reform in five hospitals, including Youyi Hospital. The MPS reform's main measures include the abolition of the drug markup, cancellation of registration and consultation expenditures, and establishment of medical service expenditure, aimed at reducing the proportion of drug expenditure in total medical expenditure and increasing that of medical service expenditure. This process maintains the link between healthcare, medicine, and healthcare insurance and strengthens the reform of healthcare insurance coverage and payment methods to reduce the burden on patients. Since 2017, this reform has been implemented in public and voluntary private medical institutions across Beijing.

Most existing studies confirm that the MPS reform has helped control medical expenditure, optimize the expenditure structure, and standardize medical practices. However, some studies indicate some of the challenges that the reform continues to face, such as the limited effect of the reform in controlling expenditure, over-reliance on government financial compensation, and rapid growth in examination and laboratory test expenditures.[10–13] With the deepening of the reform, public hospitals face the challenge of moving from scale expansion to efficiency. Given the limited health insurance funds available, the reform of health insurance payment methods such as diagnosis-related-group payment (DRG) has become an important measure to address these challenges.[14] As the first region in China to successfully develop and systematically apply DRG, Beijing Municipality developed the Beijing version of the DRG payment program (BJ-DRG). The BJ-DRG was first applied in the diagnostic and therapeutic environment in Beijing in 2008 and officially implemented DRG payment in six hospitals in July 2011. Since then, the scope of DRG payment hospitals and disease groups in Beijing has gradually expanded.[15]

Per-item payment is a post-payment system, which is not conducive to cost control. Per service unit payment is in between per item payment and disease payment.[16] Capitation payment is a pre-payment system related to the number of enrollees contracted for services by healthcare institutions, which promotes competition among primary healthcare institutions[17] Total budget payment emphasizes the purchasers' functions and responsibilities, facilitating cost control.[18] Disease payment is a pre-payment system that includes single disease payment (SDP), DRG and diagnosis-intervention packet (DIP). SDP is highly operational but covers a limited number of diseases and cases.[19] DRG payment categorizes patients into diagnosis-related groups based on the severity of diseases, the complexity of treatments, and the level of resource consumption, controlling rising costs and encouraging healthcare organizations to become more efficient.[20] DIP effectively improves the level of fine management.[21] In China, from 1998 to 2010, the predominant health insurance payment method was per item payment. From 2011 to 2017, total budget payment, SDP and other payment methods were promoted in pilot healthcare institutions. Since 2017, the composite payment method, primarily based on DRG/DIP, has been promoted with the overall goal of achieving the full coverage of the DRG/DIP payment method by the end of 2025.[22] Therefore, in the context of China, DRG payment is one of the main health insurance payment methods currently being promoted.

Studies in some European countries have shown that the implementation of DRG has helped control the growth rate of medical expenditure.[23] In the United States, studies of the impact of DRGs on medical quality and expenditure have shown that the implementation of DRG-PPS (a version of the DRG payment program) has reduced average hospitalization days, increased drug expenditure, and limited the growth rate of medical expenditure.[24,25] The implementation of K-DRGs in Australia has reduced hospitalization expenditure and controlled drug expenditure.[26,27] DRG studies in Japan, Thailand, and Korea have concluded that DRG can lead to lower medical expenditure; however, it has had an inconsistent impact on medical quality across countries.[28–30] DRG payment has long been practiced in Europe and the USA allowing for the collection of a wealth of theoretical research and practical experience. However, as the DRG payment system in China has been implemented in fewer areas and for a shorter duration, most relevant studies have been conducted on individual medical institutions and DRG groups.[31–33] Majority of the other studies used the second round of MPS reform in Beijing, which began in 2017, as the policy intervention. Since it covered public healthcare institutions across the city, it was not possible to conduct a contemporaneous control study, but only a pre-reform and post-reform control study.[34] This study uses the propensity score matching (PSM) and multi-period difference-in-difference (DID) model to analyze variations in the hospitalization expenditure level and structure of 18 municipal tertiary public MPS and non-MPS hospitals in Beijing before and after the MPS reform. In addition to PSM and multi-period DID analysis, a DDD model was employed to analyze the heterogeneity, which strengthened the use of the DID

method. Further, it conducts heterogeneity analysis of the reform effect between DRG and non-DRG payment hospitals to analyze the impact of the MPS reform on hospitalization expenditures, examine whether the application of the DRG payment system enhances the impact of the reform, and provide a reference for the next stage of the reform of public hospitals in Beijing.

Materials and Methods

Data Source

This study uses data from the Beijing Hospital Management Centre and the Beijing Medical Insurance Bureau, which collect data from the monthly statistical reports of Beijing hospitals from July 2011 to March 2017. These data sources are authentic, stable, and reliable and cover all 16 municipal districts in Beijing, with 3487 medical institutions across 29 categories, including general, Chinese medicine, and oncology. This study examines the relevant data of the 22 municipal tertiary public hospitals affiliated with the Beijing Hospital Management Centre, including statistical data on the basic information, resources, medical service volume, and hospitalization expenditure. The resources include staff, beds, equipment, housing and capital construction, and assets and liabilities. The medical service volume includes the number of inpatients and hospitalizations. Hospitalization expenditure includes the total expenditure, drug expenditure, and medical consumables expenditure. Of these data, the basic information, medical service volume, and hospitalization expenditure were provided by the Beijing Medical Insurance Bureau, and the resources were provided by the Beijing Hospital Management Center.

Sample Selection

Five hospitals in Beijing implemented MPS reform in July and December 2012, public healthcare institutions citywide in Beijing implemented the MPS reform in April 2017. Beijing began implementing DRG payment in July 2011. Therefore, to prevent other policies from interfering and accurately assess the impact of the MPS reform on public hospitals' expenditure, this study retrieved the statistical data from July 2011 to March 2017. Five hospitals that participated in the MPS reform in this study were all tertiary public hospitals affiliated with the Beijing Hospital Management Center. Therefore, to balance the number of hospitals in the treatment and control group, this study retrieved statistical data for all 22 municipal tertiary public hospitals affiliated with the Beijing Hospital Management Centre from July 2011 to March 2017. Among the 22 hospitals, four hospitals had invalid data, including missing information for individual months and resources such as the number of employees on board, and multiple outliers with zero expenditure. After excluding four hospitals with invalid data, a total of five MPS reform hospitals and 13 non-MPS reform hospitals, encompassing 18 sample hospitals over 69 months and a sample size of 1242 cases, were finally included in this study.

The study sample was divided into DRG and non-DRG payment hospitals for heterogeneity analyses based on the full sample. The sub-sample of DRG payment hospitals included three of the first five MPS reform hospitals that implemented DRG payment in July 2011 (Hospital A, Hospital B, and Hospital C) while the non-DRG payment hospitals subsample contained two of the MPS reform hospitals that did not implement DRG payment (Hospital D and Hospital E). The sample hospitals were grouped as shown in Table 1.

Variable Design and Descriptive Statistics

Outcome variables: The outcome variables in this study were the average inpatient expenditure per hospitalization and the proportion of hospitalization expenditure, including the average total expenditure, average drug expenditure, average medical consumables expenditure, the proportion of drug and medical consumables expenditure. These indicators reflect the burden of medical expenditure on inpatients and the composition of expenditure per hospitalization. Among them, drug expenditure includes Western and Chinese drug expenditures, and the proportion is the ratio of various detailed expenditures to total expenditure. It needs to be clarified that in the MPS reform, one of the measures to abolish the drug markup did not include Chinese drug tablets, so it is necessary to analyze Western drug and Chinese drug separately. Western drug refers to medicines used in modern medicine, generally made by chemical synthesis or extracted from natural products, which are used under the guidance of modern medical theory systems. Chinese drugs use Chinese herbs

Table 1 Subgroups of Sample Hospitals

Classification	Quantity	Sample Hospitals
MPS Reform Hospitals	5	A Hospital, B Hospital, C Hospital, D Hospital, and E Hospital
DRG Payment Hospitals	3	A Hospital, B Hospital, and C Hospital
Non-DRG Payment Hospitals	2	D Hospital and E Hospital
Non-MPS Reform Hospitals	13	F Hospital, G Hospital, H Hospital, I Hospital, J Hospital, K Hospital, L Hospital, M Hospital, N Hospital, O Hospital, P Hospital, R Hospital, S Hospital, and T Hospital

as raw materials and are processed through preparations to make different types of Chinese medicine products, which are used under the guidance of the basic theoretical system of Traditional Chinese Medicine (TCM).[35] Considering the non-normality of the expenditure indicators, direct regression may result in bias. Therefore, this study relies on the method of Kondo and Shigeoka to calculate the natural logarithms of the expenditure burden indicators, such as the average total expenditure per hospitalization.[36]

Explanatory variables: The explanatory variables in this study were the cross-multipliers of the hospital group and intervention situation dummy variables. In the sample hospitals, the 5 MPS reform hospitals were considered the treatment group and the 13 non-MPS reform hospitals as the control group. The hospital grouping dummy variable took the value of 1 for the treatment group and 0 for the control group. The intervention point was the first month of the MPS reform, and the intervention situation dummy variable took the value of 0 before the intervention point and 1 after the intervention point.

Control variables: To clarify the impact of the MPS reform on hospitalization expenditure and its structure, based on existing research, this study selected four observable variables (total number of employees, number of actual beds, total building area, and total assets) as control variables from the perspective of the resource characteristics of the medical institution.[37,38]

The descriptive statistical analysis results of the various variables are shown in Table 2.

Methods of Statistical Analysis

As the DID method must satisfy the assumption that the outcome variables of the treatment and control groups have parallel trends before policy intervention, and due to the potential "self-selection effect" in the MPS reform (for example,

Table 2 Descriptive Statistics of Variables

Variables	Before MPS Reform			After MPS Reform		
	MPS reform Hospital	Non-MPS Reform Hospital	p	MPS Reform Hospital	Non-MPS Reform Hospital	p
ATEPH (¥)	18,307.659	24,277.481	0.067	17,553.493	23,261.425	0.000
ADEPH (¥)	5802.060	8918.143	0.000	3990.756	7802.234	0.000
AWDEPH (¥)	5410.509	7396.389	0.001	3767.954	6436.081	0.000
ACDEPH (¥)	391.551	1521.754	0.000	222.802	1366.153	0.000
AMCEPH (¥)	6751.280	3696.641	1.000	7486.088	4149.158	1.000
PODE	0.323	0.411	0.000	0.233	0.363	0.000
POMCE	0.354	0.177	1.000	0.411	0.202	1.000
TNOHE (person)	2839.500	1376.077	1.000	3025.821	1618.644	1.000
NOAB (bed)	1367.300	716.077	1.000	1444.095	756.794	1.000
TBA (m^2)	156,425.303	67,955.098	1.000	160,094.989	78,180.231	1.000
TA (¥/thousand)	1,555,798.876	748,166.671	1.000	2,400,601.463	1,147,320.206	1.000

Note: The original data was from the Beijing Hospital Management Centre and the Beijing Medical Insurance Bureau.

Abbreviations: ATEPH, average total expenditure per hospitalization; ADEPH, average drug expenditure per hospitalization; AWDEPH, average Western drug expenditure per hospitalization; ACDEPH, average Chinese drug expenditure per hospitalization; AMCEPH, average medical consumables expenditure per hospitalization; PODE, proportion of drug expenditure; POMCE, proportion of medical consumables expenditure; TNOHE, total number of hospital employees; NOAB, number of actual beds; TBA, total building area; TA, total assets.

the hospitals of treatment groups will tend to choose general or high-level hospitals, which have better medical resources and infrastructure than specialty or low-level hospitals), a direct DID analysis method would lead to inaccurate results. PSM is a method used to construct counterfactual events from a sample of individuals in the control group with similar characteristics to an observable variable in the treatment group to control for potential "selectivity bias" owing to the inherent differences between the sample hospitals.[39] Accordingly, this study first used PSM to match a comparable sample of non-MPS reform hospitals with a sample of MPS reform hospitals and then applied DID to analyze the impact of MPS reform on hospitalization expenditure and its structure.

Propensity Score Matching

In this study, two types of hospitals in the sample were selected for PSM analysis: (1) hospitals that implemented the MPS reform from 2012 to 2017 as the treatment group and (2) hospitals that had not implemented MPS reform from 2012 to 2017 as the control group. Based on existing studies, this study adopted PSM, proposed by Rosenbaum and Donald, selected four observable variables (total number of employees, number of actual beds, total building area, and total assets) as covariates, and matched the hospitals in the treatment and the control groups.[40]

In this study, logit models for propensity score and kernel matching compared with the nearest neighbor and radius matching methods were used. The kernel matching method can strengthen the use of the initial samples and thus retain relatively complete sample information. Therefore, the analysis results are closer to the true effect. In kernel matching, the hospitals that implemented the MPS reform were matched not only to the closest distance control group individuals but also to individuals in the entire control group. The weights were calculated based on the propensity score distance from the match, with the closest distance given the largest weight. The kernel matching estimator is shown in (Equation 1).

$$\mathrm{ATT} = \frac{1}{n_1}\sum_{i\in D_i}\left\{Y_{1i} - \frac{\sum_{j\in C} Y_{0j} G((P_j - P_i)/h_n}{\sum_{k\in C} G((P_k - P_i)/h_n}\right\} \quad (1)$$

where h_n is the specified bandwidth and $G(\cdot)$ is the kernel function. Let Y_{1i} represent hospitalization expenditure and the structure of MPS reform hospitals and Y_{0j} represent the hospitalization expenditure and the structure of non-MPS reform hospitals. When $D_i = 1$ represents the set of MPS reform hospitals, n_1 represents the total number of individuals, when $D_i = 0$ represents the set of non-MPS reform hospitals. P represents the propensity score. $C(i)$ denotes the set of MPS reform hospital individual i and the matched non-MPS reform hospital individuals.

In this study, the quality of matching was assessed by comparing the standard deviation, t-test values, and pseudo-R^2 values of covariates before and after matching.

Difference-in-Difference and Difference-in-Difference-in-Difference

Given that the five MPS reform hospitals had different intervention time points, with hospitals A and B having implemented the reform since July 2012 and hospitals C, D, and E since December 2012, the standard DID method, which typically sets a uniform policy intervention time point, is not suitable. Therefore, this study uses "multi-period DID" with a non-uniform policy intervention time point based on inpatient expenditure data to determine the impact of the MPS reform on hospitalization expenditure and its structure.[41] The multi-period DID model is shown in (Equation 2).

$$Y_{it} = \beta_0 + \beta_1 Treat_i * Period_{it} + \lambda X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (2)$$

where Y_{it} is the outcome variable representing the hospitalization expenditure or the structure of sample individual i in period t; $Treat_i$ is the hospital subgroup dummy variable (treatment group = 1, control group = 0); $Period_{it}$ is the intervention situation dummy variable (pre-intervention = 0, post-intervention = 1); $Treat_i * Period_{it}$ is the cross-multiplier of the hospital subgroup and intervention situation dummy variables; X_{it} is a series of control variables introduced; $Y_i$and δ_t denote the medical institution's individual and time fixed effects, respectively, and ε_{it} is the random error term.

To calibrate the heterogeneity effect between DRG and non-DRG payment hospitals, the "whether it is a DRG payment hospital" variable is introduced to expand the DID baseline model, and a difference-in-difference-in-difference (DDD) model is constructed.[42] This is shown in (Equation 3).

$$Y_{it}=\beta_0+\beta_1 Treat_i * Period_{it}+\beta_2 Treat_i * Period_{it} * Drg_i+\lambda X_{it}+\gamma_i+\delta_t+\varepsilon_{it} \quad (3)$$

where $Treat_i$ * $Period_{it}$ * Drg_i is the triple cross term of the DRG payment hospitals, the MPS reform hospitals, and the policy intervention situation variable. Its coefficient reflects the difference in effect of whether the hospital is a DRG payment hospital. Drg_i is a dummy variable, with $Drg_i = 1$ indicating that it is a DRG payment hospital and $Drg_i = 0$ indicating that it is a non-DRG payment hospital. Other variables are consistent with the DID baseline model.

Results

Propensity Score Matching results

The PSM results are shown in Table 3. After kernel matching, except for the total assets variable, the standard deviations for each matching variable in the treatment and control groups are controlled within 10%. The *t*-test results also show that the differences between the treatment and control groups are not significant for each matching variable, except for total assets. In addition, the total bias after matching is significantly reduced to 11.5%, and the pseudo-R^2 in the regression results is significantly smaller, from 0.602 to 0.070 (Table 4), indicating that the use of PSM can effectively reduce the differences in the matching variables between the treatment and control groups, such that the changes in the explanatory variables in the logit regression do not have much explanatory power, and it eliminates the estimation bias caused by the sample self-selection to a degree. Overall, the difference between the treatment and control groups after matching is acceptable.

Full-Sample DID Regression Results

The full-sample DID regression analysis results are shown in Table 5. The coefficients of $Treat_i$ * $Period_{it}$ reflect the impact of the MPS reform on hospitalization expenditure and its structure.

Table 3 Matching Feature Variables (Taking the Natural Logarithm) Matching Balance Test Results

Variables	Before/ After Match	Variable mean		Standard deviation (%)	Deviation reduction (%)	t-Statistic	P value
		Treatment group	Control group				
TNOHE	Before Match	7.972	7.225	185.2	98.0	25.98	<0.001
	After Match	7.988	8.003	−3.8		−0.38	0.706
NOAB	Before Match	7.247	6.444	149.1	96.3	19.98	<0.001
	After Match	7.190	7.220	−5.5		−1.65	0.100
TBA	Before Match	11.926	11.121	194.8	94.7	28.81	<0.001
	After Match	11.973	11.930	9.4		0.89	0.374
TA	Before Match	14.579	13.540	169.8	84.4	23.42	<0.001
	After Match	14.427	14.589	−26.5		−3.18	0.002

Abbreviations: TNOHE, total number of hospital employees; NOAB, number of actual beds; TBA, total building area; TA, total assets.

Table 4 Matching Quality Test Results of Different Matching Methods for Relevant Indicators

Matching method	Pseudo-R^2	Standard deviation (%)	Likelihood ratio statistic
Before match	0.602	174.700	882.890
Kernel matching	0.070	11.500	36.010
1:2 nearest neighbor matching	0.083	12.400	42.850
Radius matching	0.085	16.900	35.870

Table 5 DID Model results: Impact of the MPS Reform on Hospitalization Expenditures (Taking the Natural Logarithm) and Structure

Variables	ATEPH (SE)		ADEPH (SE)		AWDEPH (SE)		ACDEPH (SE)		AMCEPH (SE)		PODE (SE)		POMCE (SE)	
$Treat_i$*$Period_{it}$	−0.056**	−0.039	−0.218***	−0.245***	−0.220***	−0.246***	−0.208***	−0.241***	−0.055*	−0.025	−0.031***	−0.045***	0.021***	0.027***
	(0.024)	(0.037)	(0.026)	(0.04)	(0.026)	(0.04)	(0.05)	(0.073)	(0.03)	(0.042)	(0.004)	(0.006)	(0.006)	(0.007)
TNOHE		0.115		−0.302		−0.266		−0.744		0.018		−0.133***		0.148***
		(0.455)		(0.436)		(0.434)		(0.635)		(0.425)		(0.035)		(0.04)
NOAB		−0.070		0.015		0.055		−0.512**		−0.472***		0.073***		−0.087***
		(0.131)		(0.129)		(0.13)		(0.201)		(0.131)		(0.014)		(0.021)
TBA		0.105		−0.015		−0.004		−0.189*		0.084		−0.012*		0.000
		(0.081)		(0.082)		(0.083)		(0.103)		(0.082)		(0.006)		(0.010)
TA		0.045		−0.019		−0.021		0.005		0.074		−0.009		0.010
		(0.052)		(0.055)		(0.055)		(0.079)		(0.058)		(0.006)		(0.009)
cons	9.812***	7.852***	8.090***	10.405***	7.940***	9.647***	6.226***	16.532***	5.571***	6.779**	0.214***	0.859***	−0.948***	−0.611*
	(0.125)	(2.947)	(0.124)	(2.786)	(0.125)	(2.766)	(0.15)	(4.707)	(0.12)	(2.812)	(0.009)	(0.269)	(0.263)	(0.324)
adj. R^2	0.708	0.706	0.748	0.745	0.751	0.749	0.753	0.757	0.979	0.979	0.97	0.973	0.984	0.985

Notes: ***P < 0.01; **P <0.05; *P < 0.1. Robust standard errors (SE) in parentheses. The "*" in "$Treat_i$*$Period_{it}$" represents multiplication.
Abbreviations: TNOHE, total number of hospital employees; NOAB, number of actual beds; TBA, total building area; TA, total assets.

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The results showed that after PSM matching, compared with non-MPS reform hospitals, in MPS reform hospitals, the average total expenditure per hospitalization remained stable (P = 0.380), the average drug, Western drug and Chinese drug expenditures per hospitalization decreased by 24.5%, 24.6%, and 24.1%, respectively (P < 0.001), and the average medical consumables expenditure per hospitalization did not change significantly (P = 0.550).

Compared with the non-MPS reform hospitals, the results in the MPS reform hospitals showed that after PSM matching, the proportion of drug expenditure decreased by 4.5% (P < 0.001), and the proportion of medical consumables expenditure increased significantly by 2.7% (P < 0.001).

Heterogeneity Analysis Results

Studies have found that DRG payment changes hospitals' revenue-generation mode through packaged payment, which helps control arbitrary increases in medical expenditure, improve medical efficiency, and regulate medical behaviors.[43] Meanwhile, some studies have found that DRG payment may pose problems such as unnecessary increases in medical items, resulting in serious losses.[44,45] The results of the DDD model are shown in Table 6. After matching, the $Treat_i$ * $Period_{it}$ * Drg_i coefficients show that the average Chinese drug expenditure per hospitalization, the average medical consumables expenditure per hospitalization, and the proportion of medical consumables expenditures are statistically significantly reduced after implementing MPS reform in DRG payment hospitals. These coefficients are much smaller than those of the DID model. This indicates that the policy effects of the MPS reform for DRG payment hospitals exceed that of non-DRG payment hospitals.

In order to further compares and analyzes the effects of the implementation of DRG payment on the outcomes of the MPS reform. It conducts heterogeneity analysis of the effect of the MPS reform on the DRG and non-DRG payment hospitals based on a full-sample regression model. Specifically, the hospitals that implemented the MPS reform in 2012 were further divided into two types: DRG and non-DRG payment hospitals. A group regression analysis was then conducted to test the effects of the MPS reform on hospitalization expenditures in DRG and non-DRG payment hospitals. The results of the heterogeneity analyses are shown in Table 7.

The results showed that the MPS reform had no significant impact on the average total expenditure per hospitalization in DRG (P = 0.731) and non-DRG payment hospitals (P = 0.789). In terms of drug expenditure per hospitalization, the MPS reform in DRG payment hospitals resulted in a significant decrease by 22.5%, 21.1%, and 48.3% (P < 0.001), respectively, in the average drug, Western drug and Chinese drug expenditures per hospitalization. The MPS reform in non-DRG payment hospitals led to a significant decrease by 30.9%, 31.5% (P = 0.001), and 24.6% (P = 0.020), respectively, in the average drug, Western drug and Chinese drug expenditures. In terms of consumable expenditure, the MPS reform did not significantly affect the average medical consumables expenditure per hospitalization of DRG (P = 0.213) and non-DRG payment hospitals (P = 0.611), indicating that although DDD models show that the MPS reform has a stronger policy effect of medical consumables expenditure DRG payment hospitals than in non-DRG payment hospitals, they are not significant.

In terms of the proportion of drug expenditure, the MPS reform led to a significant decrease in the proportions of drug expenditure in DRG payment hospitals by 5.5% (P < 0.001), and a significant decrease in the proportions of drug

Table 6 Hospitalization Expenditure (Taking Natural Logarithms) and Structure DDD Model Result

Variables	ATEPH (SE)	ADEPH (SE)	AWDEPH (SE)	ACDEPH (SE)	AMCEPH (SE)	PODE (SE)	POMCE (SE)
$Treat_i$*$Period_{it}$	−0.039	−0.255***	−0.264***	−0.129*	0.011	−0.042***	0.038***
	(0.032)	(0.036)	(0.036)	(0.069)	(0.038)	(0.006)	(0.007)
$Treat_i$*$Period_{it}$*Drg_i	0.003	0.039	0.067	−0.422***	−0.135**	−0.010*	−0.043***
	(0.054)	(0.054)	(0.054)	(0.093)	(0.056)	(0.006)	(0.007)
cons	7.826**	10.037***	9.018***	20.468***	8.040**	0.953***	−0.207
	(3.347)	(3.148)	(3.118)	(4.999)	(3.142)	(0.285)	(0.316)
R^2	0.705	0.745	0.748	0.766	0.979	0.973	0.986

Notes: ***P < 0.01; **P <0.05; *P < 0.1. Robust standard errors (SE) in parentheses. The "*" in "$Treat_i$*$Period_{it}$" and "$Treat_i$*$Period_{it}$*Drg_i" represents multiplication.

Table 7 Heterogeneity Test Results for Hospitalization Expenditure (Taking Natural Logarithms) and Structure

Groups	Variables	ATEPH (SE)	ADEPH (SE)	AWDEPH (SE)	ACDEPH (SE)	AMCEPH (SE)	PODE (SE)	POMCE (SE)
DRG payment hospital	$Treat_i$*$Period_{it}$	−0.019	−0.225***	−0.211***	−0.483***	−0.080	−0.055***	0.002
		(0.056)	(0.057)	(0.055)	(0.112)	(0.064)	(0.009)	(0.010)
	cons	7.036**	8.655***	8.178***	11.063**	6.586**	0.514	0.041
		(3.165)	(2.860)	(2.821)	(5.228)	(3.082)	(0.329)	(0.344)
	R^2	0.618	0.664	0.68	0.673	0.979	0.976	0.990
Non-DRG payment hospital	$Treat_i$*$Period_{it}$	−0.026	−0.309***	−0.315***	−0.246**	−0.047	−0.057***	0.050***
		(0.099)	(0.092)	(0.092)	(0.105)	(0.093)	(0.009)	(0.010)
	cons	5.689	12.942	11.906	21.765**	11.622	1.994***	−1.144**
		(9.502)	(8.662)	(8.627)	(9.407)	(8.458)	(0.586)	(0.512)
	R^2	0.679	0.735	0.739	0.784	0.98	0.976	0.989

Notes: ***P < 0.01; **P <0.05; *P < 0.1. Robust standard errors (SE) in parentheses. The "*" in "$Treat_i$*$Period_{it}$" represents multiplication.

expenditure in non-DRG payment hospitals by 5.7% (P < 0.001). Regarding the proportion of medical consumables expenditure, the MPS reform did not significantly affect the proportion of medical consumables expenditure in DRG payment hospitals (P = 0.812), but significantly increased the proportion of medical consumables expenditure in non-DRG payment hospitals by 5.0% (P < 0.001).

Robustness Tests

In this study, robustness tests were conducted by replacing the PSM method with the 1:2 nearest neighbor and radius matching methods, respectively. The quality tests of the relevant indicators of different matching methods are shown in Table 4. After matching, the standard deviation of the matching variables was reduced from 174.7% to 11.5%–16.9%, and the total bias was significantly reduced. The pseudo-R^2 decreased from 0.602 before matching to 0.070–0.085 after matching and the likelihood ratio statistic decreased from 882.890 before matching to 35.870–42.850 after matching. The results are generally consistent and the matching results are robust.

The regression results are consistent with the above. The MPS reform significantly reduces the average drug, Western and Chinese drug expenditures per hospitalization in MPS reform hospitals. Due to space constraints, this study only presents the results of the impact of the MPS reform on hospitalization expenditure (taking the natural logarithm) under radius matching (Table 8).

Table 8 Robustness Test Results

Variables	ATEPH (SE)	ADEPH (SE)	AWDEPH (SE)	ACDEPH (SE)	AMCEPH (SE)
$Treat_i$	−0.036	−0.243***	−0.248***	−0.186***	−0.028
*$Period_{it}$	(0.043)	(0.045)	(0.046)	(0.053)	(0.046)
TNOHE	0.170	−0.287	−0.228	−0.884	0.414
	(0.734)	(0.690)	(0.690)	(0.728)	(0.664)
NOAB	−0.060	0.021	0.090	−0.869**	−0.659**
	(0.259)	(0.242)	(0.242)	(0.274)	(0.115)
TBA	0.106	−0.015	−0.017	−0.023	0.173
	(0.120)	(0.119)	(0.120)	(0.125)	(0.115)
TA	0.041	−0.026	−0.023	−0.077	0.025
	(0.044)	(0.048)	(0.048)	(0.060)	(0.050)
cons	7.423	10.330*	9.318	18.870***	10.483*
	(2.945)	(5.101)	(5.001)	(5.462)	(4.875)
R^2	0.766	0.798	0.801	0.831	0.984

Notes: ***P < 0.01; **P <0.05; *P < 0.1. Robust standard errors (SE) in parentheses. The "*" in "$Treat_i$*$Period_{it}$" represents multiplication.

Discussion

The results of the study are summarized as follows. First, the MPS reform controlled the rapid and sustained growth of hospitalization expenditure and optimized its internal structure. The average total expenditure per hospitalization in the MPS reform hospitals remained stable; meanwhile, the MPS reform has led to a significant decrease in the average drug expenditure per hospitalization by 24.5%, the proportion of drug expenditure by 4.5%. The Asia-Pacific region is positioned as the second largest global market for pharmaceuticals and medical devices, behind North America. With an advanced stage of population aging and an increased number of middle-class citizens, there is an increasing demand for innovative pharmaceuticals, which corresponds with expensive reimbursement prices. Prompted by these circumstances, a host of nations across the Asia-Pacific region, including Japan, South Korea, and countries within the ASEAN bloc, have begun adopting cost-effectiveness-based resource allocation and implementing annual price cuts.[46–49] However, the long-term sustainability and potential impacts of these reforms warrant further observation and examination.

Second, the MPS reform significantly increases the proportion of medical consumables expenditure, with the DRG payment system helping to control this tendency. In the full-sample model, the proportion of medical consumables expenditure increased by 2.7% in MPS reform hospitals after the reform. In the sub-sample model, the proportion of medical consumables expenditure increased significantly by 5.0% in non-DRG payment hospitals, whereas it did not increase significantly in DRG payment hospitals. This may be because medical consumables have many models and are classified in various ways, making it difficult to manage using generic names like drugs.[50] Supplier-induced demand is one of the significant reasons leading to an unintended consequence, where the prices of medical consumables and other non-technical services increased in hospitals after the reform. This phenomenon is prevalent in the healthcare systems of high-income countries such as the United States and Canada, and middle-income countries such as China, Vietnam, and Brazil.[49,51–54] DRG payment builds a compensation model of "cost control is more compensation" through the prepayment system and effectively regulates supplier-induced demand. This ultimately supports the MPS reform in establishing a long-term cost-control mechanism for drugs and consumables.[55]

Third, the MPS reform has generally had a more positive effect on DRG payment hospitals than non-DRG hospitals, but there remains room for improvement. The average drug expenditure per hospitalization and the proportion of drug expenditure decreased by 22.5% and 5.5%, respectively, in the DRG payment hospitals. The decrease in average drug expenditure per hospitalization was lower in DRG payment hospitals than in non-DRG payment hospitals, whereas the decrease in the proportion of drug expenditure in DRG payment hospitals was similar to that in non-DRG payment hospitals. However, the proportion of medical consumables expenditure in non-DRG payment hospitals increased significantly after the MPS reform, indicating that the decrease in the proportions of drug expenditure in non-DRG payment hospitals was offset by an increase in the proportion of medical consumables expenditure rather than an increase to technical services. The "cost control" effect of non-DRG payment hospitals was contradictory to the MPS reform objectives. The smaller decrease in average drug expenditure per hospitalization in DRG payment hospitals may be due to the restricted autonomy of doctors, increased workload of non-medical operations, and the lack of supporting measures under the DRG payment system, which have reduced doctors' motivation to participate in the reform.[56,57] DRG payment incentivizes hospitals to control costs and improve efficiency through financial leverage. Consequently, hospitals strategically respond to the incentives of the DRG-based payment system and explore ways to maximize profits.[58] This implies that the combination of DRG payment and other healthcare reforms, such as the MPS reform, may lead to unintended consequences. As of 2023, a total of 49 countries internationally have introduced DRG-based hospital payment systems, including 15 middle-income countries such as China, Malaysia, and Thailand. Additionally, 13 countries are piloting or exploring the use of DRG-based hospital payment systems, including 12 middle-income countries such as Vietnam and the Philippines.[59] Owing to potential long-term patterns of epidemic and the resulting increase in healthcare expenditures, low- and middle-income countries are experiencing a crisis of financial sustainability.[60,61] This situation makes DRG-based hospital payment systems receive increasing attention and usage in middle-income countries compared to high-income countries.[62] Therefore, continuously monitoring the interaction between DRG payment and healthcare reforms, and dynamically updating payment methods and reform measures, can contribute to achieving the intended objectives.

Based on these findings, this study makes the following recommendations: First, monitoring of medical consumables should be strengthened and unreasonable compensation should be controlled. Doctors' clinical experience should be translated into purchasing needs and the circulation links of consumables should be reduced through pooled purchasing. Second, this study suggests supervising the process of procurement, storage, and use of consumables, developing a catalog for the use of consumables, establishing quantitative supervisory indicators, and using "relative measurement" to rationalize the mechanism of resource allocation.[63,64] Third, the MPS and DRG payment linkage reforms should be promoted and further reform of DRG payment schemes should be explored. Currently, the DRG payment reform still faces problems, such as out-of-date standards, unrefined grouping, and practical operability, which require improvement. In the future, we should establish a unified DRG standard system, strengthen the construction of DRG information infrastructure, and encourage medical staff to participate in the program design, implementation, and evaluation to ensure doctor's autonomy and simultaneously refine, rationalize, and operationalize DRG payment programs.[65] Fourth, we should strengthen the MPS reform and increase doctors' motivation to participate. The motivation of medical staff is a key factor in the success of healthcare reforms,[66] thus, the unification of residual claims and control rights for doctors should be promoted.[67] The dividends from the medical insurance fund balance should be earmarked for internal performance distribution in hospitals and DRG payment should be implemented to deepen public hospital personnel's performance appraisal system through indicators such as the CMI (case mix index) and CEI (charge consumption index) indices to evaluate the performance of medical services and doctors in various departments.[68,69] This will enable horizontal comparisons among hospitals, departments, and doctors to increase the value of technical services, ensure high-quality development of medical services, and achieve reasonable cost control and optimization of the expenditure structure in the long term.

Limitations of This Study

This study still has several limitations. Firstly, limited by the number of hospitals with MPS reform, only a small sample of hospitals could be selected. Secondly, to conduct a contemporaneous control study and prevent other policies from interfering, only the study period of July 2011–March 2017 could be selected. In the future, with further promotion of the MPS reform and DRG payment system, we can select a wider range of sample and time individuals for the study. Thirdly, the subjects of this study were from Beijing, and although its policy effects as the capital mega-city and the first city to implement DRG payment may provide a reference for healthcare reform in other regions, the results may not reflect the effects of the MPS reform and health insurance system reform interventions beyond Beijing.

Conclusion

This study analyses the policy effects of the first MPS reform in Beijing, which began in 2012, and has implications for subsequent MPS reform. This is one of the first studies to analyze the heterogeneity in DRG payment hospitals for the MPS reform, which is innovative for the linkage between the MPS reform and DRG payment, based on the analysis of the impact of the MPS reform on hospitalization expenditure and its structure in tertiary public hospitals. The MPS reform had a significant effect on controlling rapid and sustained increases in hospitalization expenditure and optimizing its structure. The MPS reform has led to a decline in the average drug expenditure per hospitalization and the proportion of drug expenditure. DRG payment helped lower the proportion of medical consumables expenditure that increased after the MPS reform and enhanced the outcomes of the reform. It is proposed to strengthen the management of medical consumables in the future, promote the MPS reform and DRG payment linkage, and improve reform support measures to ensure positive, long-term effects of the reform.

Abbreviations

MPS, medical–pharmaceutical separation; DRG, diagnosis-related-group; PSM, propensity score matching; DID, difference-in-difference; DDD, difference-in-difference-in-difference; CMI, case mix index; CEI, charge consumption index.

Data Sharing Statement

The data were collected from the Beijing Hospital Management Centre and Beijing Medical Insurance Bureau. The datasets can be accessed and used for academic research with the permission of the human resources management office in Beijing Hospital Management Centre and the office in Beijing Medical Insurance Bureau. The datasets are not publicly available.

Ethical Approval

This study was reviewed by the Medical Ethics Committee of Beijing Cancer Hospital and granted exemption from ethical review. In accordance with the guidelines of relevant documents "Measures for Ethical Review Involving Human Beings and Biomedical Research" (the National Health and Family Planning Commission of the People's Republic of China Decree No. 11), Chapter 1, Article 3, this study does not involve subject protection and ethical approval was not required.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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