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The impacts of China's drug price zero-markup policy on medical expenditures and health outcomes

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ABSTRACT

Drug overuse and high drug expenditures have long been of concern in China. In 2012, the Chinese government implemented the drug price zero-markup policy (ZMP) to contend with these problems. This paper investigates the impact of the ZMP on the hospitalization expenses and health outcomes of inpatients, using administrative data from Beijing. The findings show that the ZMP reduces inpatients' medicine expenses by an average of 20.4%, while total hospitalization expenses do not change significantly. The findings also show that the average length of hospital stay increases by 0.588 days. The results jointly indicate that hospitals adopt substitution behavior to make up for the drug revenue loss. The paper finds no evidence that the ZMP has a negative impact on patients' probability of death or readmission.

1. Introduction

In China, drug overuse has long been a major concern in the health care system. For example, the number of antibiotics used in China was twice the number recommended by the World Health Organization (WHO) (Li et al., 2012), and the percentage of patients who were prescribed antibiotics in outpatient care during 2010–2012 was as high as 45.7% (Yin et al., 2013). Drug overuse also drives high expenditures. Spending on drugs accounts for nearly 40% of total health spending in China, while in most Organization for Economic Co-operation and Development (OECD) countries, this proportion is only 17% (Health at a Glance 2019, OECD). Drug expenditure for inpatient care accounts for 41.3% of total expenditure, generating a leading part of health care expenditure, which not only creates a fiscal burden for social insurance but also reduces the affordability of medical care for the population (Yip & Hsiao, 2009).

In a new wave of health care reform, the Chinese government has implemented a series of policies to contend with these drug problems, including the drug price zero-markup policy (ZMP), national centralized drug procurement and negotiation, and other policies. The most influential policy is the ZMP. Hospitals could earn up to 15% from drug sales before the reform, and the ZMP completely eliminated the profit margin. The policy was first implemented in pilot cities and lower-level hospitals, such as primary and secondary hospitals, and then expanded to all public hospitals in China.

This paper investigates the impacts of the ZMP on inpatient expenses and health outcomes. Using an individual-level administrative data set, we employ a staggered difference-in-differences (DID) method to address the impact of the ZMP on inpatient expenses,

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including medicine expenses and different categories of non-medicine expenses. Furthermore, we explore the heterogeneous effects of the ZMP along different dimensions, including severity level of disease, health insurance type, gender and age. To investigate the impact of the ZMP on health outcomes, we use death and readmission as measurements of health outcomes.

We find that after the implementation of the ZMP, the medicine expenses of inpatients dropped by 20.4% on average. The result indicates that the ZMP has effectively reduced drug expenditures. The ZMP eliminates the 15% profit margin, hence generating a reduction in drug prices. If the quantity of drug consumption remains the same, it is expected that drug expenditures would decrease by about 15%. However, the actual reduction in drug expenditure reaches 20.4%, suggesting that the quantity of drug consumption may also have decreased or some prescriptions are switched to cheaper brands. Conditional on the decrease in drug price, the change in drug consumption is more likely driven by the providers, i.e., physicians and hospitals, rather than the patients. Before the reform, prescribing more drugs or more expensive ones could generate profit for the providers. However, when the financial incentive of drug sales is taken away, physicians react and prescribe drugs as deemed necessary.

Although the drug expenditures have decreased, we find that the total hospitalization expenses remain about the same, and non-medicine expenses actually increase. The finding suggests that providers adapt to the ZMP, and develop new strategies to generate revenue. The reduction in the medicine expenses is substituted by the increase in the expenditures on non-drug services. Combined together, the ZMP does not lessen the financial burden for the insurer or patients.

The results from heterogeneity analysis show that the decline in medicine expenses is higher for patients with severe conditions, patients not insured by the New Rural Cooperative Medical System (NRCMS), males and older patients. The results are reasonable. These kinds of patients may suffer from severe conditions or have used more (expensive) medicines, so the reduction in drug expenditures is more for them than for other patients. We also consider the ZMP's impact on the length of stay (LOS), and it turns out that the ZMP increases LOS by an average of 0.588 days. Extending LOS may be a way to increase non-medicine services, as staying longer in the hospitals would involve more services for the patients, such as nursing care and bed fees. Meanwhile, substitutional services induced by financial incentives, like lab tests and radiological examinations, would take time to produce the results, which also contributes to the increase in LOS. Furthermore, we investigate the impacts of the ZMP on patients' health outcomes. No negative impacts on death or readmission (10, 15, and 30 days) are found, suggesting that the structure change of drug and non-medicine services has not negatively affected patients' health outcomes.

Our study contributes to the literature on the physician agency problem and drug overuse. The physician agency problem has been raised in the past (Ginsburg & Hogan, 1993; Gruber & Owings, 1996), and several studies show that physicians respond to financial incentives in the medical market and drug prescription process (Clemens & Gottlieb, 2014; Einav, Finkelstein, & Mahoney, 2018; Ho & Pakes, 2014; Iizuka, 2012). There is also evidence suggesting that in China, physicians' prescribing behavior is affected by factors unrelated to patients' medical conditions (Currie, Lin, & Meng, 2014; Lu, 2014; Wu, 2019). The reduced quantity of drugs prescribed or the reduced prescriptions for high-price drugs, indirectly derived from the finding of the 20.4% reduction in drug expenditures, suggests that physicians may have actively changed their drug prescriptions because of the elimination of the profit on drug sales.

This study also expands the literature on evaluating the impact of the ZMP. Previous studies mainly focused on the ZMP's impacts on hospital income and individual expenditures. From the perspective of hospitals, drug income decreases while total income remains at the origin level; thus, the ZMP brought unintended effects through supply-side-induced services (Pan, Cui, & Li, 2015; Yi, Miller, Zhang, Li, & Rozelle, 2015). At the individual level, medicine expenses are found to have decreased for both inpatient and outpatient care, while expenses for other medical services have increased (Chen, Song, & Zhang, 2018; Fu, Li, & Yip, 2018; He & Zhou, 2017; Li, Liu, Chen, & Yao, 2008; Song, Chen, & Yin, 2016; Zhou et al., 2015). Our results are consistent with the results of previous studies in terms of the decrease in medicine expenses and unchanged total expenses. In addition, while these studies do not provide evidence on the ZMP's impacts on health outcomes, we provide direct evidence of the ZMP's impacts on patients' health outcomes. According to our analysis, no negative impacts were found in terms of probability of death and readmission.

This paper is one of only a few to study the impact of the ZMP in Beijing's general hospitals. As the capital city, Beijing attracts lots of patients from the rest of China, with its intensive and high-quality health care resources, providing a wide and unique field to study the policy impact. Some of the previous studies used hospital management data or community health center data (Li et al., 2008; Song et al., 2016) and lacked control groups for comparison. The study that is most relevant to ours is by Zeng, Chen, Fu, Lu, and Jian (2019), who find that after implementation of the ZMP, total hospitalization expenses and medicine expenses per inpatient decrease in the short term in the pilot hospitals, but in the long term the difference vanishes. However, Zeng et al. do not provide evidence on the ZMP's impact on health outcomes. Furthermore, their sample is patients only covered by the Urban Employee Basic Medical Insurance. Our sample includes patients with all types of insurance.

The rest of the paper proceeds as follows. Part 2 describes the institutional background, introducing the relevant national-level policy context of this study, the pilot policy in Beijing, and information on the focal disease in this study. Part 3 presents the data and descriptive statistics. Part 4 explains the empirical strategy and identification problems. Part 5 presents the empirical results. Part 6 provides conclusions and reflections, summarizing the main findings of the paper, reflecting on the research process, and making suggestions for future research.

2. Institutional background

2.1. Drug zero-markup policy

The price of health care services in China has been fixed at a relatively low level since the establishment of the state, to ensure the accessibility of medical services for the majority. In 1954, to support the operation of public hospitals, the Chinese central government implemented the drug price markup policy nationwide. The policy allowed hospitals to earn markups from prescribing drugs, specifically, the markup of western medicine was not to exceed 15%, and that of Chinese patent medicine was not to exceed 16%. The income from prescribing medicines was exempt from taxes, which meant that all the income, including the markups, was reserved for public hospitals (Zhang & Bian, 2007). In the early 1980s, China began to carry out market-oriented reforms. From then on, subsidies to public hospitals dropped from 40% of total revenue to 10% on average (Blumenthal & Hsiao, 2005). While the subsidies received by public hospitals fell, the prices of medical services were still uniformly fixed, making it difficult for hospitals to adjust prices independently.

Given the low fiscal subsidies and fixed, low prices for health care services, the drug price markup policy gradually created the hospital's profit-seeking motivation, emerging as a physician agency problem. While most health facilities in China are public in terms of ownership, they are actually for-profit in operation due to the low subsidies and fixed prices for health services (Yip & Hsiao, 2009). Thus, the drug price markup policy was meant to support the operation of public hospitals by indirectly subsidizing them through price markups. Public hospitals had to rely on drug revenue to maintain their basic operations and development. Fig. 1 shows that from 2002 to 2012, medicine expenses accounted for 52.8% of total outpatient expenditure and 43.2% of total inpatient expenditure per visit on average, dominating individual health care expenditures and hospital income.

The profit-seeking motivation induced by the drug price markup policy raised major concerns. The first concern is the huge health care expenditure driven by prescriptions (Chen et al., 2014). According to data released by the Chinese National Health Commission, the share of drug expenditure for inpatients accounted for 41.3% of total expenditure per visit, generating a leading part of expenditure on health care as well as driving its rapid growth. High health care expenditure not only creates a fiscal burden for social health insurance, but also leads to unaffordable access for citizens (Yip & Hsiao, 2009). The second concern is drug overuse, especially in terms of antibiotics (Yip, Hsiao, Meng, Chen, & Sun, 2010). Although medical expenditure grew at over 10% annually over the past decade in China, there was not a corresponding improvement in the quality of care. Oversupply, especially over-prescription, played the main role in causing this problem (Eggleston, Ling, Qingyue, Lindelow, & Wagstaff, 2008). Previous studies show that physicians' prescription behavior is likely to be influenced by financial incentives (Iizuka, 2012), leading to drug overuse (Currie et al., 2014; Li et al., 2012). Evidence of the physician agency problem in terms of prescriptions has also been found in China (Lu, 2014; Wu, 2019; Yip et al., 2010), indicating that drug overuse in China needs serious consideration. Among drug overuse, antibiotic abuse is the most serious, as it threatens public health by creating antibiotic-resistant "superbugs." In China, the number of antibiotics used was twice the number recommended by the WHO (Li et al., 2012), and the overall percentage of outpatients who were prescribed antibiotics during 2010–2012 was 45.7% (Yin et al., 2013).

Given these concerns, in 2009, China launched a new wave of health system reforms, including the reform of public hospitals as a core focus. The reform of public hospitals eliminates the drug price markup, lowers the inspections and prices of large-scale medical equipment, and increases the prices of items that reflect the value of the medical staff's technical services. Elimination of the drug price markup has an important position in this reform, accounting for its function of incentive adjustment for providers. Specifically, in April 2012, the Chinese government issued the policy aiming to abolish the drug price markup, that is, the ZMP.

Beijing, as the capital, took the lead in piloting the ZMP in some hospitals right after the release of the national policy. The pilot policy in Beijing was to abolish the 15% markup as well as cancel the registration fee and diagnosis and treatment fee. Alternatively, the pilot policy allowed hospitals to charge fees for medical services as compensation. However, the effect of policies other than the ZMP is likely to be minor for inpatient services. The medical service fee is set between 42 and 100 yuan, depending on the professional title of the physician, which is far lower than the change in the drug expenses. Hence, the impacts we observed after the reform may mainly be driven by the ZMP, but not other policies implemented at the same time. Five tertiary public general hospitals participated in the pilot reform, with one starting implementation of the ZMP in July 2012, another in September, and the other three in December. Among the pilot hospitals, the first two are tertiary general hospitals providing comprehensive medical care, and the other three are outstanding in specialty medical care.

2.2. Chronic obstructive pulmonary disease (COPD)

This paper focus on patients with acute exacerbation of chronic obstructive pulmonary disease (COPD). COPD is a disease characterized by continuous airflow restriction that can be prevented and treated. COPD has already become a worldwide public health issue in terms of prevalence, mortality, and burden of healthcare costs. The age-standardised COPD mortality per 100 thousand people is 291 around the world. As for the burden of disease, COPD ranks sixth in the leading cause of disability-adjusted life year (DALY) among all age groups and the fourth among people aged between 50 and 74 in 2019 (Burney, Patel, Newson, Minelli, & Naghavi, 2015; Global Burden of Disease Study 2019, 2020).[1] COPD is also associated with a substantial economic burden worldwide. For example, the cost of COPD each year is estimated to be approximately 50 billion in the USA (National Institutes of Health, 2009).

COPD has an even higher prevalence in China. Using a unique dataset from the China Pulmonary Health (CPH) study, Wang et al. (2018) estimates that the prevalence of COPD in China is 8.6% in 2015, and further speculates that there are 99.9 million COPD patients in China. Another research by Fang et al. (2018) shows that the prevalence of COPD in China is 13.6% by applying national representative data from 2014 to 2015, and there is a huge difference between males and females. COPD creates a heavy economic burden for the patients as well. The total cost per COPD patient per admission in a major city in 2016 is 24,372.75 yuan, in which

[1] The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

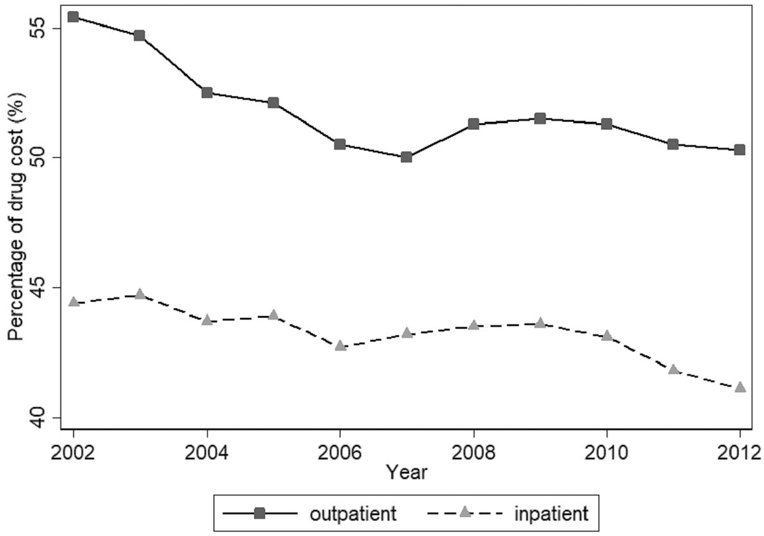

Fig. 1. Share of drug costs in inpatient and outpatient total costs in public hospitals, 2002–2012 (%).
Note: (a) The data are from the China Health Statistics Yearbooks, 2003–2013. (b) The y-axis represents the percentage of drug costs in total hospital costs.

western medicine fee is the biggest contributor (Li et al., 2018). In the focal city Beijing, the total costs per COPD patient per admission increased from 19,760 yuan in 2009 to 20,118 yuan in 2017 (Liang et al., 2020).

In summary, COPD is a disease with a high prevalence and a high mortality rate. It also causes a heavy economic burden for the society. Despite that we could only focus on the single disease of COPD due to the data limitation, investigating the response to the healthcare reform for patients with COPD has strong policy relevance and practical significance in the Chinese healthcare system.

3. Data

The data set contains the inpatient medical records for patients with acute exacerbation of chronic obstructive pulmonary disease (COPD) in all hospitals in Beijing from January 1st, 2012 to June 30th, 2015. Beijing implemented a drug procurement policy in July 2015, which also affected the expenses on drugs; therefore, to ensure a clean identification, data after June 2015 are not included in the sample. The tertiary hospitals are the top-ranking hospitals in China, and they are in general of large scale, providing high-quality treatment. Given that the pilot hospitals are all tertiary ones, we exclude samples from secondary and lower-level hospitals. We also exclude one pilot hospital that does not provide records before the reform. Therefore, patients in the remaining four pilot hospitals serve as the treatment group, and patients in the remaining thirty-two tertiary hospitals that did not implement the ZMP serve as the control group.

In addition, we exclude the patients whose total hospitalization expenses were less than 500 yuan from the sample.[2] We also exclude patients younger than 18 years old due to the feature of COPD.[3] After excluding missing values, our sample contains 57,372 admissions for analysis. The summary statistics are provided in Table 1, with information on demographics and hospitalization-related variables. Column 1 shows the statistics for all patients. One-third of the patients are female, which is comparable to the nationwide statistic (Wang et al., 2018). The average age is 74.5, and over 90 % of the patients are married. 89.40% of the patients live in Beijing, and more than half of them are insured by Urban Employee Basic Medical Insurance (UEBMI).

When a patient is admitted to the hospital, his/her daily living ability is assessed by a standard evaluation system. Specifically, the system consists of ten questions, evaluating whether the patients could independently conduct activities such as eating, taking a shower, and walking. Each question ranges from 0 to 10, and higher scores indicate better health status. In general, if the assessment score of daily living ability at admission (ability score for short) of a patient is above 60, it means that he/she could take care of himself/herself. If the score is below 20, it means that the patient is completely incapable. The scores between twenty to sixty mean the patient needs some help in daily activity. As shown in Column 1, the mean of the ability score is 68.90. About 20% of patients' ability is assessed below 40, and nearly 70% of patients are with scores above 60.

Although the pilot hospitals were not randomly assigned, we build our random assumption on individual behavior. Since the information on the pilot hospitals of the ZMP for drugs is public information, a potential problem is that after the reform, patients may be more willing or unwilling to choose a pilot hospital, which raises the concern about endogeneity. Two factors may help to alleviate

[2] It's very likely to be a recording error, if the total expenses are less than 500 yuan.

[3] COPD has a higher prevalence among people aged above 40 years while smoking is a main causative factor, adolescents under 18 years old are less likely to get COPD, previous studies also use patients above 20 years old to conduct analysis (Wang et al., 2018).

Table 1
Descriptive statistics of patients' demographics.

	All patients	Pilot hospitals		Non-pilot hospitals	
		Before	After	Before	After
	(1)	(2)	(3)	(4)	(5)
Sex (%, female)	33.61	33.34	33.66	37.35	33.05
Age (years)	74.50	73.02	74.87	75.31	74.79
Marital status (%)					
Married	90.36	94.72	89.28	88.82	89.42
Single	6.84	5.06	7.28	7.31	7.22
Missing	2.80	0.22	3.44	3.87	3.36
Residence (%, Beijing)	89.40	83.85	90.77	86.52	91.88
Health insurance type (%)					
UEBMI	52.28	53.89	51.88	51.80	51.88
URBMI	7.79	15.03	6.00	6.36	5.69
NRCMS	10.89	6.99	11.86	13.42	11.49
Other	29.04	24.09	30.26	28.42	30.94
Ability score	68.90	73.22	67.81	69.20	67.53
Ability score by category (%)					
≤40	17.78	14.40	13.77	17.97	18.95
40–60	14.39	15.63	14.23	14.80	14.21
≥ 60	67.83	69.97	72.00	67.23	66.84
Observations	57,372	1465	8303	5475	34,744

Note: (a) NRCMS refers to New Rural Cooperative Medical Scheme; UEBMI refers to Urban Employee Basic Medical Insurance; URBMI refers to Urban Resident Basic Medical Insurance. Ability score refers to assessment score of daily living ability at admission. Other insurance type contains free health care service insurance, commercial health care insurance, and etc. Single includes unmarried, widowed and divorced. (b) We define January 2012–June 2012 as before the ZMP, July 2012–June 2015 as after the ZMP.

it. The first is that even if the pilot program is public information, it is very likely that patients are unaware of the reform in pilot hospitals due to their lack of attention. The second is that Beijing's medical resources are relatively scarce, and sometimes patients have to wait for a few days for admission because of the lack of vacant beds. For patients with the need of inpatient care, it is more important to be admitted to a hospital, with or without ZMP, than choose a hospital they prefer. Therefore, the pilot policy information may not have a great impact on patient selection.

To explore the issue, we display the main demographic variables of patients in pilot hospitals and non-pilot hospitals before and after the ZMP was implemented, shown in Columns 2 to 5 in Table 1. Some distributions of demographics are stable, such as gender and age, as shown in Columns 2 and 3, the mean age of patients is 73 and 75 in pilot hospitals before and after the ZMP, while in non-pilot hospitals, the mean age is both nearly 75. The fraction of local patients has increased in pilot hospitals after the reform, while it has decreased in non-pilot hospitals. According to the statistics for the ability score, patients are less healthy after the reform in pilot hospitals, while the pattern reverses in non-pilot hospitals. In all admission-level regression analyses, we control for all patients' demographics shown in Table 1. To further control for potentially different time trends across patients of different demographics and health status, we also include the interactions between individual's demographic characteristics as well as ability score and linear time trends in all regression analyses.

Table 2 summarizes the statistics on outcome measures, including medicine expenses, non-medicine expenses, total hospitalization expenses, death, readmission, and length of stay.[4] Medicine expenses are divided into two categories, western medicine expenses, and Chinese patent medicine expenses.[5]

Column 1 in Table 2 shows the statistics for pilot hospitals before the ZMP. The average of total expenses is 18,240 yuan for inpatient admissions at pilot hospitals. The average of medicine expenses is 8904 yuan, accounting for about one-third of the total expenses. The average of western medicine expenses is 8751 yuan, accounting for the majority of the medicine expenses. The average of non-medicine expenses is 9335 yuan. The probability of death is 0.13%, and the probability of readmission within 30 days, 15 days, and 10 days are 5.60%, 3.89%, and 3.34%, respectively. The average LOS in pilot hospitals is 12.23 days before the ZMP.

Column 4 in Table 2 illustrates the statistics for non-pilot hospitals before the ZMP. The total hospitalization expenses are similar between these two types of hospitals, but medicine expenses are higher in non-pilot hospitals. The probability of death in pilot hospitals is 0.13%, compared with 0.28% in non-pilot hospitals. In addition, the probabilities of readmission in non-pilot hospitals are higher than those in pilot hospitals. The differences in probability of death and readmission also indicate pilot hospitals provide a higher quality of healthcare. Despite the differences in expenses between pilot and non-pilot hospitals, we validate in our following

[4] By our definition, medicine expenses include expenses for Western medicines, Chinese patent medicines, and Chinese herbal medicines, among which Western medicines and Chinese patent medicines are both impacted by the ZMP. We mainly focus on the first two kinds of medicine expenses, but when analyzing total medicine expenses, we include Chinese herbal medicines.

[5] Chinese patent medicine are herbal medicines in Traditional Chinese medicine, modernized into a ready-to-use form such as tablets, oral solutions or dry suspensions, as opposed to herbs that require cooking.

Table 2
Descriptive statistics of inpatient expenses, health outcome and length of stay.

	Pilot hospitals			Non-pilot hospitals			Diff-in-Diff
	Before	After	Diff	Before	After	Diff	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total hospitalization expenses (yuan)	18,239.94 (16,186.67)	18,507.99 (15,989.10)	268.05	18,581.99 (15,244.61)	19,191.64 (16,059.43)	609.65	−341.6***
Medicine expenses (yuan)	8904.14 (9311.98)	7613.57 (7909.71)	−1290.57	9036.07 (8370.03)	9045.50 (8070.31)	9.43	−1300.99***
Western medicine (yuan)	8750.99 (9240.83)	7456.27 (7846.64)	−1294.75	8645.83 (8129.44)	8488.09 (7844.46)	−157.74	−1127.98***
Chinese patent medicine (yuan)	131.85 (238.82)	339.35 (789.42)	−207.5	144.53 (250.63)	515.58 (964.84)	−371.05	−163.55***
Non-medicine expenses (yuan)	9334.81 (9386.17)	10,968.42 (9676.49)	1633.61	9471.91 (9543.63)	10,146.15 (9729.20)	674.24	959.38**
Health outcome							
Death (%)	0.13 (3.69)	1.04 (10.15)	0.91	0.28 (5.26)	0.45 (6.75)	0.17	0.74***
Readmission within 30 days (%)	5.60 (23.00)	9.35 (29.11)	3.75	8.95 (28.55)	16.95 (37.52)	8	−4.25***
Readmission within 15 days (%)	3.89 (19.34)	6.72 (25.04)	2.83	6.56 (24.77)	13.00 (33.63)	6.44	−3.61***
Readmission within 10 days (%)	3.34 (17.98)	5.86 (23.49)	2.52	5.54 (22.88)	11.39 (31.77)	5.85	−3.33***
Length of stay (days)	12.23 (6.62)	13.65 (8.28)	1.42	11.65 (6.18)	13.42 (7.43)	1.77	−0.35
Observations	1465	8303		5475	34,744		

Note: (a) Standard deviations are in parentheses. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) We define January 2012–June 2012 as before the ZMP, July 2012–June 2015 as after the ZMP.

analysis that these differences remain parallel before the ZMP. Column 3 reports the differences between the pilot hospitals before and after the ZMP. Similarly, Columns 2, 5 and 6 present the statistics for pilot and non-pilot hospitals after the ZMP, and their differences. In Column 7, we show the difference-in-difference (DID) statistics. Without any controls, the difference in the average total expense between the pilot and non-pilot hospitals decreases by 342 yuan after the reform. The average medicine expenses decrease by 1301 yuan and the average non-medicine expenses increases by 959 yuan. There is an increase in probability of death and a decrease in probability of readmission in pilot hospitals. However, these patterns are only preliminary, and more careful analyses using control variables are provided in sections below.

4. Empirical strategy

Since the four pilot hospitals began implementing the new policy at different times, this paper applies a staggered DID method to identify the impact of ZMP on patients' medical expenses and health outcomes. The model is as follows:

$$y_{ijt} = \alpha + \beta_1 * ZMP_{ijt} + \gamma * X_i + u_j + u_{y*m} + X_i * f(t) + \epsilon_{ijt} \tag{1}$$

Where subscript i refers to the admission, j refers to the hospital, and t refers to time. The dependent variable, y_{ijt}, indicates the expenses or health outcome of the patient of admission i received medical care in hospital j at time t, which enters the regression in logarithmic form. The core explanatory variable, ZMP_{ijt}, its coefficient indicates the impact of the policy between pilot hospitals and non-pilot hospitals. If the admission i occurs at hospital j when the hospital begins implementing the reforms, ZMP_{ijt} equals one. X_i is a set of control variables at the individual level, including age, age squared, gender, assessment score of daily living ability at admission, residence, marital status, and the type of health insurance. u_j is the fixed effect at the hospital level, which captures the unobservable hospital-level heterogeneity among different hospitals. u_{y*m} is the fixed effect at the year*month level to capture the overall time trend. $X_i * f(t)$ includes a set of interaction terms between linear time trends and individual's predetermined characteristics, including gender, age bins, marital status, residence and health insurance type, which controls for time trends across groups of different demographics. $X_i * f(t)$ also includes an interaction term between linear time trends and patient's ability score bins to control for different time trends across patients with different underlying health status.

The main coefficient of interest is β_1, which captures the average treatment effect on the treated (ATT) of the ZMP on the medical expenses and health outcomes of patients in the pilot hospitals. The standard errors are clustered at hospital level. In addition, the observations come from 36 hospitals (clusters), and the model may suffer from a "few cluster" problem. To verify our estimation, we conduct wild cluster bootstrap following the literature (Cameron, Gelbach, & Miller, 2008; Cameron & Miller, 2015) and provide the wild cluster bootstrap p-value at the bottom of each table.

For a robustness test, we also apply the standard DID method to identify the impact of the policy by excluding the period during which the reform occurred (July 2012 to December 2012). The model is as follows:

$$y_{ijt} = \alpha + \beta_2 * pilot_j * post_t + \gamma * X_i + u_j + u_{y*m} + X_i * f(t) + \epsilon_{ijt} \quad (2)$$

If the admission i occurs at hospital j, which is a pilot hospital, then $pilot_j = 1$; otherwise, $pilot_j = 0$. If the admission i occurs after the reform started, then $post_t = 1$; otherwise, $post_t = 0$. The core explanatory variable is $pilot_j * post_t$, and β_2 captures the ATT of the ZMP on the medical expenses and health outcomes of patients in the pilot hospitals. The other elements of model (2) are the same as those of model (1) of staggered DID model.

The basic assumption of DID analysis is that the trends of the control and treated groups before policy implementation must be parallel, supporting that the change between the two groups after the policy implementation is driven by the policy impact rather than the preexisting difference in trends. To test the parallel pre-trends, we use the dynamic DID model shown below to identify differences in the pre-trends at the monthly level.

$$y_{ijt} = \alpha + \sum_{s=-11}^{35} \beta_s \times ZMP_{ijt}(t = T_j + s) + \gamma * X_i + u_j + u_{y*m} + X_i * f(t) + \epsilon_{ijt} \quad (3)$$

Similar to the staggered DID model, the subscript i refers to the admission, j refers to the hospital, and t refers to time. The dependent variable, y_{ijt}, indicates the expenses or health outcome of the patient of admission i receiving medical care in hospital j at time t. Since we conduct this model at the monthly level, i.e., for the hospitals implement ZMP in July 2012, there are six pre-treatment months and thirty-five post-treatment months; as for the hospitals implement ZMP in December 2012, there are eleven pre-treatment months and thirty post-treatment months. Thus, there are forty-seven periods in total for all treated hospitals, s is from -11 to 35, including period 0 as the period when the ZMP was implemented. T_j indicates the relative starting month of ZMP of hospital j in all forty-seven periods. If admission i occurs at hospital j when it just starts to implement the reform in month s, ZMP_{ijt} equals 1. β_s captures the dynamic effect of the ZMP. The other notations are the same as those of the staggered DID model.

5. Results

5.1. Baseline results

We first illustrate the results of dynamic DID model. Fig. 2 shows the results of the parallel pre-trends test with medicine expenses as the outcome variable. Since the policy started in different months in the pilot hospitals, we denote the starting month as month 0. The benchmark period is the first month before the start of the policy. It shows that the coefficient is not significantly different from 0 before the policy starts, which implies that the parallel pre-trends hypothesis holds, suggesting that the pilot and non-pilot hospitals have similar patterns in medicine expenses before the policy starts. Medicine expenses in pilot hospitals relative to non-pilot hospitals immediately drop in the first period after the policy starts, and the reduction becomes greater through the implementation of the policy. The coefficient of the reduction on medicine expenses stabilizes at about -20% in later years.

Figs. 3, 4, 5 show the parallel pre-trends results with non-medicine expenses, total hospitalization expenses and LOS. We could see there exist no significant pre-trends before the implementation of the ZMP in terms of non-medicine expenses, total hospitalization expenses and LOS. The parallel pre-trends test provides intuitive evidence of time dynamics for identifying the impact of the ZMP. We use the staggered DID model to identify the ATT of the ZMP for detailed evidence. Pre-trends test of other outcomes are presented in Appendix Figs. A1-A6.

Table 3 presents the baseline regression results of staggered DID model on medicine expenses, non-medicine expenses, total hospitalization expenses, and LOS. The coefficient of ZMP is the core of interest. After the policy implementation, medicine expenses in pilot hospitals drop by 20.4% on average, compared to that in non-pilot hospital.[6] Table A1 reports the detailed coefficients estimated under different combinations of control variables, fixed effects and time trends, suggesting that the estimations are stable. The ZMP reduces patients' medicine expenses at a rate that is higher than the allowed drug markup before the reform (15%). We speculate that the reduction could be driven through three channels. First, the medicine expenses are directly reduced by decreased prices through the elimination of the drug price markup. Second, there is a direct decrease in quantity: since hospitals cannot obtain profit from drug sales, there may be a reduction in the quantity of medicines prescribed. Third, physicians may prescribe less expensive drugs after the ZMP; thus, the price structure of the prescribed drugs tends to be more concentrated at the lower end, contributing to the overall decline in medicine expenses.

In addition, Columns 2 and 3 in Table 3 show that the regression coefficients of non-medicine expenses increase by 13.5%, and the total hospitalization expenses increase by 2.2% (insignificant). These results imply that hospitals and physicians are carrying out substitution behavior, increasing non-medicine expenses to make up for the loss of profits from the drug price markup.

We also examine the impact of the ZMP on the length of stay. The results in Column 4 show that after the implementation of the ZMP, the average LOS for inpatients increases by 0.588 day. One channel of the increase in LOS is that physicians provide more non-medicine services to make up for revenue loss from drug sales. Providing more non-medicine services could lead to a longer hospital stay. For example, it takes time to get the results of lab tests and radiological examination. This behavior may be motivated by the financial incentives since the ZMP essentially cuts down the hospital revenue, and physicians expect to prescribe more non-medicine services to make up for the loss. This behavior can also arise because physicians may have concerns about the potential reduction in

[6] When the value is low, 20.4 log points is nearly equal to 20.4%. Unless otherwise noted, the conversion method is the same in the following.

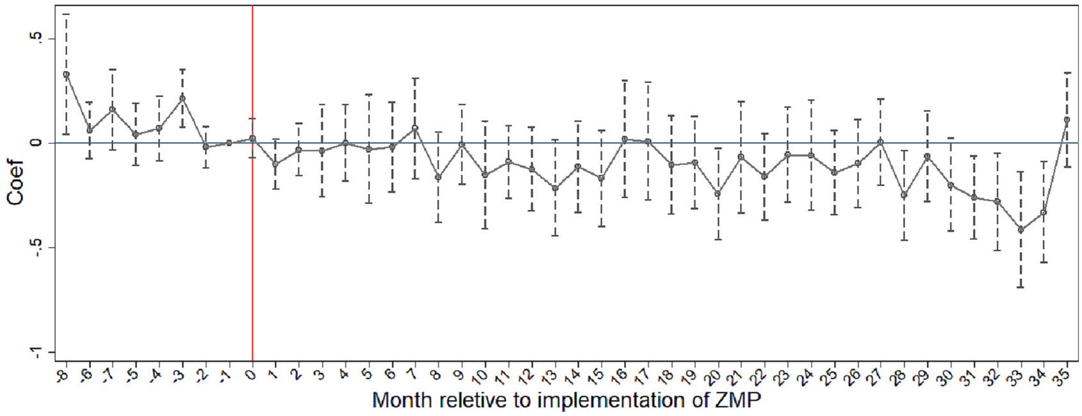

Fig. 2. Parallel trends (event study) of medicine expenses.
Note: (a) Dependent variable is medicine expenses. (b) Pre and post are defined at the month level. (c) The benchmark period is the month before implementation of the ZMP.

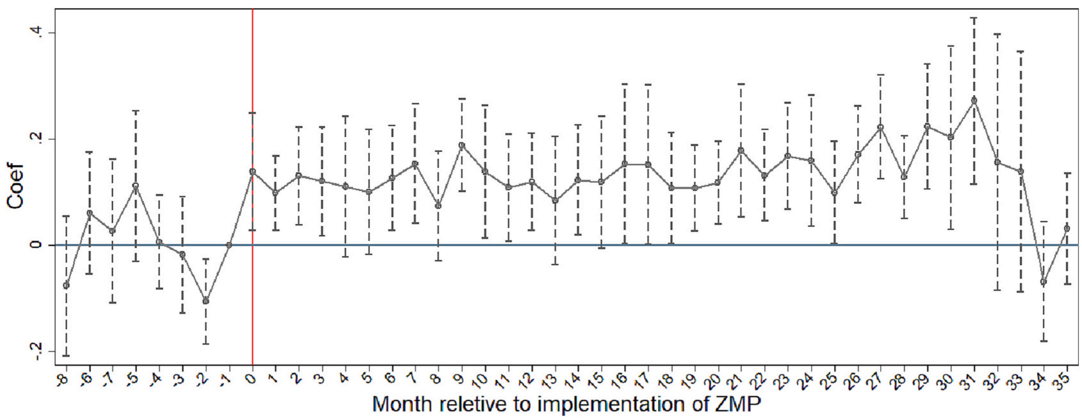

Fig. 3. Parallel trends (event study) of non-medicine expenses.
Note: (a) Dependent variable is non-medicine expenses. (b) Pre and post are defined at the month level. (c) The benchmark period is the month before implementation of the ZMP.

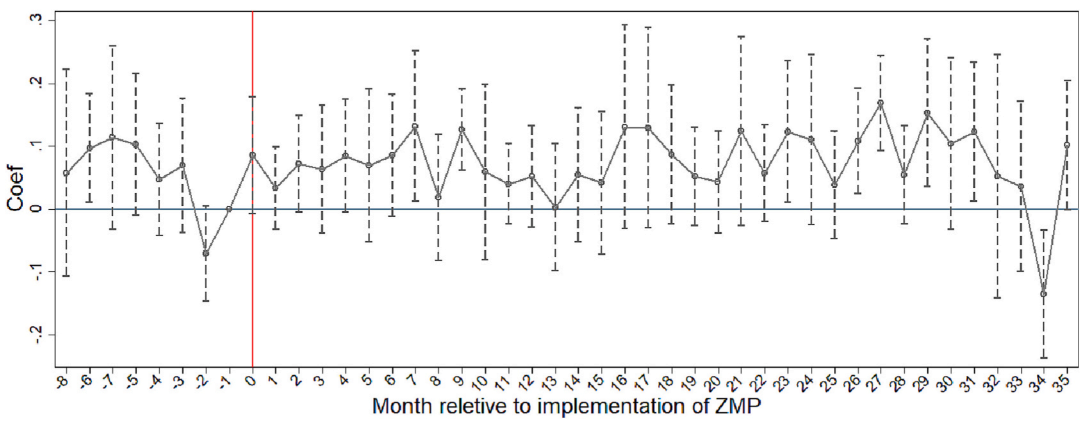

Fig. 4. Parallel trends (event study) of total hospitalization expenses.
Note: (a) Dependent variable is total hospitalization expenses. (b) Pre and post are defined at the month level. (c) The benchmark period is the month before implementation of the ZMP.

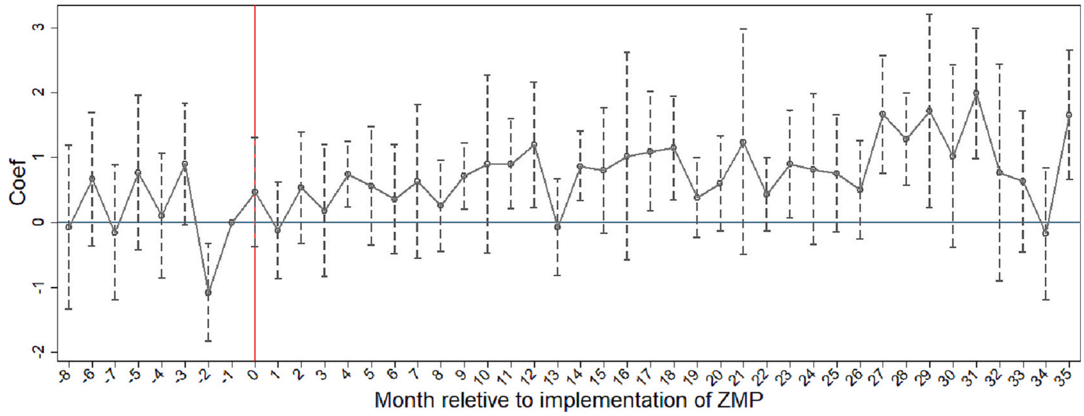

Fig. 5. Parallel trends (event study) of length of stay.
Note: (a) Dependent variable is length of stay. (b) Pre and post are defined at the month level. (c) The benchmark period is the month before implementation of the ZMP.

Table 3
ZMP impact on expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of stay
	(1)	(2)	(3)	(4)
ZMP	−0.204**	0.135***	0.022	0.588**
	(0.090)	(0.022)	(0.019)	(0.246)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	57,372	57,372	57,372	57,372
R^2	0.206	0.301	0.264	0.154
WCB p-value	0.004	0.000	0.272	0.036
Mean of D.V.	8905.136	9334.809	18,239.940	12.229

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

quality of care, as the patients have consumed less medicines or cheaper substitutes. Although there is no evidence on health deterioration induced by ZMP in our work and other previous studies, physicians may still have concerns about it.

Another potential channel is that physicians prescribe a longer hospital stay to make up for the financial loss since longer hospital stay may naturally induce more health care costs. However, the literature suggests that the extension of hospital stay may have a limited impact on overall inpatient expenditure in China. For example, Yan, Cheng, Chen, Liu, and Ning (2022) show that the first few postoperative days are more costly than the days before discharge. Meanwhile, tertiary hospitals have strict controls over the length of stays in order to improve turnover rates (Ren et al., 2020). Besides, studies focusing on healthcare systems in other countries also found that the costs directly attributable to the last day of admission are an economically insignificant component of total costs, implying that reducing LOS has limited cost-saving potential (Evans et al., 2018; Taheri, Butz, & Greenfield, 2000).

We are also interested in identifying which categories of medicine decrease and which category of non-medicine expenses increase. Table 4 shows the effects of the ZMP on different categories of medicine and non-medicine expenses. After the implementation of the ZMP, for medicine expenses, western medicine expenses drop by 19.5% and Chinese patent medicine expenses drop by 21.4% as shown in Columns 1 and 2 of Table 4. Meanwhile, in the non-medicine expenses, the expenses for diagnosis and treatment, nursing, general treatment, and disposable medical materials for examinations all increase significantly. Expenses for diagnosis and treatment increase by 170.8 log points, nearly 452%; nursing expenses increase by 126.6 log points (nearly 2.5 times); general treatment expenses increase by 68.4 log points (nearly 98%); disposable medical materials for examination expenses increase by 39.0 log points (48%). The results are intuitive. Examinations and nursing care are in general more discretionary than general treatment or medical materials, so we found the most increase in expenses in the former categories.

Table 4
ZMP impact on medicine and non-medicine expenses, by category.

	Medicine expenses		Non-medicine expenses			
	Western medicine expenses	Chinese patent medicine expenses	Medical examination and treatment expenses	Nursing expenses	General treatment expenses	Disposable medical materials expenses
	(1)	(2)	(3)	(4)	(5)	(6)
ZMP	−0.195**	−0.214	1.708***	1.266**	0.684**	0.390*
	(0.089)	(0.178)	(0.214)	(0.506)	(0.309)	(0.220)
Controls	Y	Y	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y	Y	Y
Observations	57,372	57,372	57,372	57,372	57,372	57,372
R^2	0.210	0.275	0.520	0.389	0.310	0.192
WCB p-value	0.004	0.220	0.000	0.164	0.064	0.244
Mean of D.V.	8750.993	131.847	99.532	48.567	59.250	198.674

Note: (a) The dependent variables are the log expenses on western medicine, Chinese patent medicine, examination and treatment, nursing, general treatment, and disposable medical materials. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB p-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

5.2. Robustness test

In this section, we conduct five robustness tests to support our baseline results. First, we exclude the period of time when the policy was progressively implemented in pilot hospitals (from July 2012 to December 2012) and use the standard DID model as a robustness test. After excluding this period, the total sample size is 49,987. Tables A2 and A3 report the results for medicine expenses, non-medicine expenses, total hospitalization expenses, LOS and different categories of medicine expenses as well as non-medicine expenses. According to Table A2, the change in medicine expenses estimated by standard DID (−23.3%) is similar to the results estimated by staggered DID (−20.4%). Similarly, coefficients of total expenses are not statistically significant. The increase in the length of stay is about 0.536 days. Table A3 presents the robustness results on two categories of medicine expenses and four categories of non-medicine expenses, the results are highly similar to staggered DID. That is, reductions in both subcategories of medicines (western and Chinese medicine), and increases in all non-medical subcategories.

A growing literature suggests that the staggered DID estimator can be explained as the ATT only under homogeneous treatment assumptions (Callaway, & Sant'Anna, P. H. C., 2021; Goodman-Bacon, 2021). To alleviate the concern that our estimation is biased, we conduct a Bacon Decomposition as a second robustness test based on Goodman-Bacon (2021) and Stevenson and Wolfers (2006) by reshaping our data into a hospital-month level panel data. Table A4 shows the weights and DID estimators using Bacon Decomposition, the results show that the weight of all two-group comparisons are positive and the weight of the treatment group and never-treatment group is 0.977. Fig. A7 presents the detailed weights and coefficients.

As a third approach of robustness test, we identify the patients who were hospitalized before and after the ZMP as a sub-sample, which helps to alleviate the problem of patients' self-selection. Table A5 shows the results of the regression using this subsample. Medicine expenses drop by an average of 27.1%, which is higher than the baseline result, it may be because patients with multiple hospitalizations are likely to be severe, thus, medicine expenses drop more for them. The coefficients of total hospitalization expenses and non-medicine expenses are positive, implying a substitution behavior.

We conduct a fourth robustness test by limiting the sample period from January 2012 to December 2013, thus we preserve 12 months after the reform to make the sample more balanced. We conduct this analysis to address the concern that the time periods before and after the policy are not balanced in the baseline analysis, for there are 11 pre-treatment months and 36 post-treatment months. The results are shown in Tables A6 and A7. The estimations with restricted sample periods are similar to the baseline results, except that some estimates are a little lower in absolute value compared to the baseline estimates. It is explainable that the treatment effects have not been fully revealed within a shorter period.

In the baseline model, we include interactions between demographics and linear time trends. To allow for squared and cubic time trends, we conduct a fifth robustness check by including interactions between demographics and squared/cubic time trends. The results are shown in Tables A8 and A9, which are essentially similar to those in the baseline model.

5.3. Heterogeneity

The baseline regression results provide the average effects of the ZMP on medical expenses. Next, we investigate the heterogeneous impacts of the ZMP on medicine expenses for different groups by applying the triple-difference (DDD) framework. We test the heterogeneous impact of the ZMP in terms of the severity level of the patient's disease, as well as their type of health insurance, age and gender.

We first test the heterogeneity of the impact at different levels of severity of disease. The assessment score of daily living ability at admission is used as a proxy variable for the severity of the disease. If the patient's score is higher than the median (=75), then *severe* equals zero and we consider them to be mild patients, and if it is lower than the median, then *severe* equals one otherwise. Column 1 in Table 5 shows the results of severity heterogeneity. The results indicate that compared to patients with mild illnesses, there is a 17.6% larger decrease in medicine expenses for patients with severe illnesses. This result is intuitive. On the one hand, severe patients use more drugs; on the other hand, severe patients use more expensive drugs. Therefore, after the implementation of the ZMP, there was a larger decrease in the medicine expenses of severely ill patients.

We are also interested in that whether the ZMP may have heterogeneous impacts on patients who have different types of medical insurance. For this heterogeneity test, we divided patients into two groups based on their type of health insurance: $NRCMS = 1$ if patients are insured with NRCMS and $NRCMS = 0$ if patients are insured with non-NRCMS.[7] As shown in Column 2 in Table 5, the results show that compared to patients with non-NRCMS, those with NRCMS have a fewer reduction in medicine expenses. Since the reimbursement rate is relatively low for patients with NRCMS, even before the implementation of the ZMP, physicians tend to prescribe low-price medicines for them. Therefore, the price structure of patients with NRCMS does not change too much after the implementation of the ZMP.

As mentioned in the background, the prevalence of COPD has a noticeable difference between males and females due to some behavioral risk factors, such as smoking. This motivates us to conduct a heterogeneity analysis in terms of gender. As shown in Column 3 in Table 5, the decrease in medicine expenses is larger for males compared to females. The result is intuitive. In our sample, males spend more both on medicine expenses and total hospitalization, and they also have a higher readmission probability in terms of 30, 15 and 10 days. Therefore, the policy has a greater impact on male patients, which is consistent with the finding that the impact is greater for patients with severer conditions.

Finally, we focus on the heterogeneity between different age groups. we divide patients into two groups based on their age, we define $old = 1$ if patients are older than 80 years and $old = 0$ if patients are younger than 80 years. From Column 4 in Table 5 we see that older patients have a larger decrease in medicine expenses compared to younger patients, though the difference is insignificant. Older patients may be prescribed more medicines before the implementation of the ZMP, thus after the implementation, they have a slight larger medicine expenses decrease.

We also conduct heterogeneity analysis by applying regressions on subgroups classified by patients' severity level of diseases, health insurance type, gender and age. We present these results in Table A10. The results are in line with those of the DDD analysis.

5.4. *Impacts on health outcomes*

In the previous sections, we analyze the impact of the ZMP on patient hospitalization expenses and find that the ZMP reduces patients' medicine expenses burden. We are also interested in whether the ZMP has an impact on patients' health outcomes. The ZMP eliminates the incentive for physicians to prescribe unnecessary drugs. After the implementation of the ZMP, the rate of decrease in medicine expenses is greater than the drug price markup rate (15%), implying that the quantity and price structures of prescribed drugs have also changed.

Here we investigate whether the change in drug use caused by the ZMP has a negative impact on patients' health outcomes since both drug quantity and drug quality, if measured by price, declined. We analyze whether there exists any change in health outcomes after the implementation of the ZMP, measuring health outcomes by discharge status (death or otherwise) and readmission. *Death* is a dummy variable equal to one if the discharge status of the patient is "death" and equal to zero if the discharge status is "recovery, transfer or unknown reason". We also use readmission in terms of 30, 15 and 10 days. Readmission is a dummy variable equal to one if the patient is readmitted to any of the hospitals in our sample within a given period, and equal to zero otherwise.

Table 6 shows the results on health outcomes. The linear probability model (LPM) is used for the estimation. The ZMP has no significant impact on the probability of death and readmission for the patients in the pilot hospitals. Tables A11 and A12 show the results based on logit and probit models, respectively. Similarly, although the coefficients are positive, none of them are statistically significant. We conclude that there is a potential for quality deterioration due to the implementation of ZMP, but there is no solid evidence on worsened health outcomes. This is in line with our intuition and previous literature. The drug price markup gave doctors an incentive to prescribe redundant, unnecessary drugs and expensive drugs, so the marginal efficiency of treatment was limited due to the overuse of drugs. After the drug price markup was canceled, the incentive for unreasonable drug use was reduced, and the reduction in excess drug use did not have a negative impact on patients' health outcomes.

6. Conclusion and discussion

The drug price markup policy distorted physicians' behavior by providing financial incentives, leading to rapid growth in medical expenses and drug overuse. To contend with these problems, the ZMP is implemented in the new wave of medical reform in China. This paper evaluates the impact of the policy and find that after the ZMP was implemented, the average medicine expenses of inpatient care treating COPD dropped by 20.4%. This result shows that the ZMP has achieved one of the policy targets in reducing medicine expenses. The overall decline in medicine expenses of more than 15% implies that there is a decrease in the quantity and a change in the price

[7] Patients are with non-NRCMS only includes the Urban Employee Basic Medical Insurance and Urban Resident Basic Medical Insurance.

Table 5
Heterogeneity analysis on medicine expenses.

	Severity	NRCMS	Gender	Age
	(1)	(2)	(3)	(4)
ZMP	−0.116	−0.207*	−0.156*	−0.200**
	(0.088)	(0.108)	(0.0947)	(0.089)
ZMP*Severe	−0.176***			
	(0.040)			
ZMP*NRCMS		0.126***		
		(0.028)		
ZMP*Male			−0.007	
			(0.028)	
ZMP*Old				−0.071***
				(0.021)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
N	57,372	40,710	57,372	57,372
R^2	0.207	0.213	0.206	0.206
WCB p-value	0.000	0.000	0.000	0.844

Note: (a) The dependent variable is the log expenses on medicine. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB p-value refers to wild cluster bootstrap p-value with 500 replications. (f) Non-NRCMS group only includes patients with URBMI and UEBMI.

Table 6
Impact of the ZMP on readmission and death.

	Readmission within 30 days	Readmission within 15 days	Readmission within 10 days	Death
	(1)	(2)	(3)	(4)
ZMP	0.009	0.006	0.004	0.004
	(0.017)	(0.014)	(0.014)	(0.002)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	57,372	57,372	57,372	57,372
R^2	0.176	0.163	0.158	0.009
WCB p-value	0.792	0.804	0.900	0.208
Mean of D.V.	0.056	0.039	0.034	0.0013

Note: (a) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (b) Standard errors are clustered at the hospital level. (c) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (d) WCB p-value refers to wild cluster bootstrap p-value with 500 replications. (e) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

structure of prescribed medicines.

We also find that total medical expenses remain the same after the reform, as non-medicine expenses increase. The finding is intuitive and consistent with the literature showing that healthcare providers respond to financial incentives. Alleviating the drug overuse problem and optimizing the allocation of medical resources are the main goals of the ZMP. When hospital revenue is reduced because of the ZMP, providers have found alternative ways to compensate for the loss in revenue, which is reflected in the increase in non-medicine expenses. Furthermore, we analyzed the impact of the policy on patients' health outcomes. We find no evidence that the ZMP has negative impacts on patients' health outcomes in terms of probability of death and readmission.

In summary, the ZMP is achieving its goal of controlling expenses and likely alleviating drug overuse. However, hospitals have taken alternative actions to make up for the loss of hospital revenue/profit. One of these alternatives is to increase other, more flexible medical services, which may lead to another kind of oversupply. As public hospitals face various constraints on the prices of medical services, price regulations should be carefully considered, and payment reform should be implemented to provide proper incentives for hospitals.

Our study had some limitations. First, although COPD is an important public health issue and the disease is prevalent in China, it would be more informative to investigate the effects of the ZMP on the expenses of patients with other diseases. A more comprehensive analysis would explore the heterogeneous impacts of the ZMP on patients with different diseases. Second, as our sample city implemented another drug reform in the middle of 2015, the post-reform period only includes two and a half years, and we could not capture the long-term effects of the ZMP; thus, we only observe the short-term response of providers. Future studies could be undertaken to evaluate the long-term effects of the ZMP.

Data availability

The authors do not have permission to share data.

Acknowledgments

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Appendix

Table A1
ZMP impact on medicine expenses with detailed controls.

Medicine Expenses (Mean = 8905.136)	(1)	(2)	(3)	(4)	(5)
ZMP	−0.232*	−0.172	−0.139***	−0.221**	−0.204**
	(0.136)	(0.116)	(0.006)	(0.086)	(0.090)
Age		0.021***	0.020***	0.020***	0.012**
		(0.008)	(0.007)	(0.007)	(0.005)
Age squared		−0.000	−0.000	−0.000	−0.000
		(0.000)	(0.000)	(0.000)	(0.000)
Sex (male = 1)		0.125***	0.128***	0.129***	0.187***
		(0.023)	(0.015)	(0.015)	(0.031)
Ability score		−0.008***	−0.008***	−0.008***	−0.008***
		(0.001)	(0.001)	(0.001)	(0.001)
Residence (Beijing = 1)		0.065	0.142***	0.135***	0.080
		(0.058)	(0.028)	(0.031)	(0.073)
Married (unmarried = 0)		−0.239***	−0.178**	−0.190***	−0.060
		(0.078)	(0.073)	(0.073)	(0.084)
Divorced		−0.165	−0.195***	−0.212***	−0.228
		(0.124)	(0.074)	(0.076)	(0.175)
Widowed		−0.071	−0.220**	−0.231**	−0.191
		(0.104)	(0.095)	(0.095)	(0.125)
Other marital status		0.147*	−0.136	−0.163*	−0.090
		(0.080)	(0.092)	(0.093)	(0.093)
URBMI (UEBMI = 0)		−0.085	−0.007	−0.006	0.079
		(0.074)	(0.043)	(0.044)	(0.105)
NRCMS		−0.319***	−0.168***	−0.169***	−0.119*
		(0.096)	(0.029)	(0.029)	(0.072)
Other insurance type		−0.176***	−0.117***	−0.116***	−0.053
		(0.040)	(0.024)	(0.024)	(0.054)
Constant	8.753***	8.438***	8.134***	7.998***	8.150***
	(0.061)	(0.248)	(0.228)	(0.252)	(0.219)
Hospital FE			Y	Y	Y
Year*Month FE				Y	Y
Demographics*Linear time trends					Y
Observations	57,372	57,372	57,372	57,372	57,372
R^2	0.007	0.118	0.197	0.201	0.206
WCB p-value	0.667	0.308	0.000	0.000	0.004

Note: (a) The dependent variable is the log expenses on total medicines. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Ability score refers to assessment score of daily living ability at admission; NRCMS refers to New Rural Cooperative Medical Scheme; UEBMI refers to Urban Employee Basic Medical Insurance; URBMI refers to Urban Resident Basic Medical Insurance. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications.

Table A2
Robustness test with standard DID model on medicine expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of stay
	(1)	(2)	(3)	(4)
Pilot*post	−0.233**	0.116***	0.002	0.536*
	(0.096)	(0.031)	(0.023)	(0.292)
Pilot	0.073	−0.292***	−0.183***	−2.723***
	(0.095)	(0.035)	(0.028)	(0.331)
Post	−0.182	0.121	−0.034	0.341

(*continued on next page*)

Table A2 (*continued*)

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of stay
	(1)	(2)	(3)	(4)
	(0.135)	(0.075)	(0.079)	(0.756)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	49,987	49,987	49,987	49,987
R^2	0.204	0.303	0.267	0.159
WCB p-value	0.000	0.000	0.976	0.088
Mean of D.V.	8905.136	9334.809	18,239.940	12.229

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A3

Robustness test with standard DID model on non-medicine expenses, by category.

	Medicine expenses		Non-medicine expenses			
	Western medicine expenses	Chinese patent medicine expenses	Medical examination and treatment expenses	Nursing expenses	General treatment expenses	Disposable materials expenses
	(1)	(2)	(3)	(4)	(5)	(6)
Pilot*Post	−0.219**	−0.286	1.784***	1.523**	0.729**	0.477*
	(0.095)	(0.200)	(0.253)	(0.610)	(0.362)	(0.275)
Pilot	0.118	0.842***	0.121	−2.819***	−0.885**	−0.553**
	(0.095)	(0.196)	(0.261)	(0.459)	(0.361)	(0.215)
Post	−0.233*	0.494*	−0.288	−0.156	−0.664	0.519**
	(0.132)	(0.265)	(0.334)	(0.262)	(0.450)	(0.239)
Controls	Y	Y	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y	Y	Y
Observations	49,987	49,987	49,987	49,987	49,987	49,987
R^2	0.208	0.277	0.544	0.361	0.315	0.190
WCB p-value	0.000	0.180	0.000	0.104	0.088	0.244
Mean of D.V.	8750.993	131.847	99.532	48.567	59.250	198.674

Note: (a) The dependent variables are the log expenses on western medicine, Chinese patent medicine, examination and treatment, nursing, general treatment, and disposable medical materials. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A4

Decomposition of two-group comparisons.[a]

Overall DID estimation: −0.197		
Two-group comparisons	Weight	Average DD estimation
Early treatment -later control	0.004	0.090
Later treatment -early control	0.019	−0.085
Treatment -never treatment	0.977	−0.200
Observations	1218	

Note: (a) We reshape our data into a hospital-month level balanced panel data with 1218 observations, containing 29 hospitals and 42 months. (b) The dependent variable is the log expenses on total medicines.

[a]This analysis applies Stata command bacondecomp, reference: Goodman-Bacon, Andrew, Thomas Goldring, and Austin Nichols. 2019. bacondecomp: Stata module for Decomposing difference-in-differences estimation with variation in treatment timing. https://ideas.repec.org/c/boc/bocode/s458676.html

Table A5
Robustness test with the multiple hospitalizations subsample on medicine expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of Stay
	(1)	(2)	(3)	(4)
ZMP	−0.271***	0.196***	0.049*	1.049***
	(0.093)	(0.041)	(0.030)	(0.399)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	18,351	18,351	18,351	18,351
R^2	0.235	0.352	0.297	0.154
WCB p-value	0.000	0.000	0.204	0.064
Mean of D.V.	8729.547	9228.151	17,957.7	12.704

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A6
Robustness test with balanced subsample on medicine expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of Stay
	(1)	(2)	(3)	(4)
ZMP	−0.176**	0.100***	0.001	0.269
	(0.088)	(0.019)	(0.018)	(0.307)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	31,067	31,067	31,067	31,067
R^2	0.225	0.295	0.254	0.127
WCB p-value	0.012	0.000	0.996	0.464
Mean of D.V.	8905.136	9334.809	18,239.940	12.229

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A7
Robustness test with balanced subsample on non-medicine expenses, by category.

	Medicine expenses		Non-medicine expenses			
	Western medicine expenses	Chinese patent medicine expenses	Medical examination and treatment expenses	Nursing expenses	General treatment expenses	Disposable materials expenses
	(1)	(2)	(3)	(4)	(5)	(6)
ZMP	−0.169*	−0.131	1.471***	0.603**	0.340	0.148
	(0.087)	(0.162)	(0.234)	(0.302)	(0.242)	(0.096)
Controls	Y	Y	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y	Y	Y
Observations	31,067	31,067	31,067	31,067	31,067	31,067
R^2	0.230	0.277	0.492	0.323	0.541	0.238
WCB p-value	0.012	0.536	0.000	0.084	0.304	0.144
Mean of D.V.	8750.993	131.847	99.532	48.567	59.250	198.674

Note: (a) The dependent variables are the log expenses on western medicine, Chinese patent medicine, examination and treatment, nursing, general treatment, and disposable medical materials. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap *p*-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A8
Robustness test with squared time trend on medicine expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of Stay
	(1)	(2)	(3)	(4)
ZMP	−0.206**	0.135***	0.021	0.568**
	(0.090)	(0.022)	(0.019)	(0.250)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Squared time trends	Y	Y	Y	Y
Observations	57,372	57,372	57,372	57,372
R^2	0.205	0.300	0.262	0.153
WCB p-value	0.004	0.000	0.316	0.048
Mean of D.V.	8905.136	9334.809	18,239.940	12.229

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A9
Robustness test with cubic time trend on medicine expenses and length of stay.

	Medicine expenses	Non-medicine expenses	Total hospitalization expenses	Length of Stay
	(1)	(2)	(3)	(4)
ZMP	−0.208**	0.134***	0.020	0.548**
	(0.089)	(0.022)	(0.019)	(0.255)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Cubic time trends	Y	Y	Y	Y
Observations	57,372	57,372	57,372	57,372
R^2	0.205	0.299	0.262	0.153
WCB p-value	0.000	0.000	0.344	0.048
Mean of D.V.	8905.136	9334.809	18,239.940	12.229

Note: (a) The dependent variables are the log expenses on total medicines, non-medicines, total hospitalizations and length of stay. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB *p*-value refers to wild cluster bootstrap p-value with 500 replications. (f) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A10
Heterogeneity analysis on medicine expenses with group regressions.

	Severity Level		Age			Insurance Type		Gender	
	Mild	Severe	18–60	60–80	80+	NRCMS	Non-NRCMS	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ZMP	−0.160*	−0.244***	−0.173**	−0.160**	−0.273**	−0.183**	−0.190	−0.213**	−0.181
	(0.097)	(0.086)	(0.084)	(0.085)	(0.110)	(0.067)	(0.125)	(0.081)	(0.114)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	27,870	29,502	7091	30,169	20,037	27,870	29,502	38,088	19,284
R^2	0.173	0.176	0.172	0.198	0.184	0.186	0.205	0.208	0.212
WCB p-value	0.076	0.000	0.016	0.000	0.004	0.020	0.088	0.000	0.144
Mean of D.V.	6260.696	11,626.49	5873.367	8794.560	10,515.23	8500.837	9307.366	8997.407	8722.098

Note: (a) The dependent variable is the log expenses on medicine. (b) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (c) Standard errors are clustered at the hospital level. (d) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (e) WCB p-value refers to wild cluster bootstrap p-value with 500 replications. (f) Non-NRCMS group only includes patients with URBMI and UEBMI. (g) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A11
Impact of the ZMP on readmission and death with logit model.

	Readmission within 30 days	Readmission within 15 days	Readmission within 10 days	Death
	(1)	(2)	(3)	(4)
ZMP	0.251	0.259	0.239	0.842
	(0.233)	(0.245)	(0.275)	(1.072)
Marginal effect	0.026	0.021	0.017	0.006
	(0.025)	(0.021)	(0.021)	(0.011)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	57,363	57,363	57,363	54,579
Log-likelihood	−19,106.136	−15,574.384	−13,975.214	−1539.481
Mean of D.V.	0.056	0.039	0.034	0.0013

Note: (a) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (b) Standard errors are clustered at the hospital level. (c) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (d) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

Table A12
Impact of the ZMP on readmission and death with probit model.

	Readmission within 30 days	Readmission within 15 days	Readmission within 10 days	Death
	(1)	(2)	(3)	(4)
ZMP	0.106	0.097	0.071	0.287
	(0.116)	(0.119)	(0.129)	(0.337)
Marginal effect	0.020	0.015	0.010	0.005
	(0.023)	(0.019)	(0.018)	(0.008)
Controls	Y	Y	Y	Y
Hospital FE	Y	Y	Y	Y
Year*Month FE	Y	Y	Y	Y
Demographics*Linear time trends	Y	Y	Y	Y
Observations	57,363	57,363	57,363	54,579
Log-likelihood	−19,150.362	−15,620.386	−14,023.386	−1539.1719
Mean of D.V.	0.056	0.039	0.034	0.0013

Note: (a) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (b) Standard errors are clustered at the hospital level. (c) Control variables include age, age squared, gender, residence, marital status, and health insurance type, as in Table A1. (d) Mean of D.V. refers to the mean value of dependent variable of treated group before the implementation of ZMP.

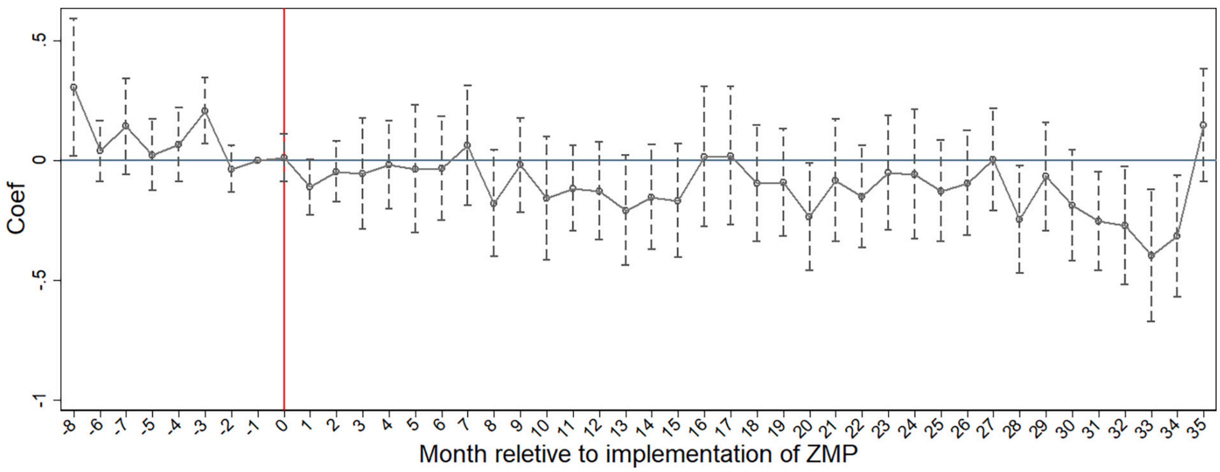

Fig. A1. Parallel trends of western medicine expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP.

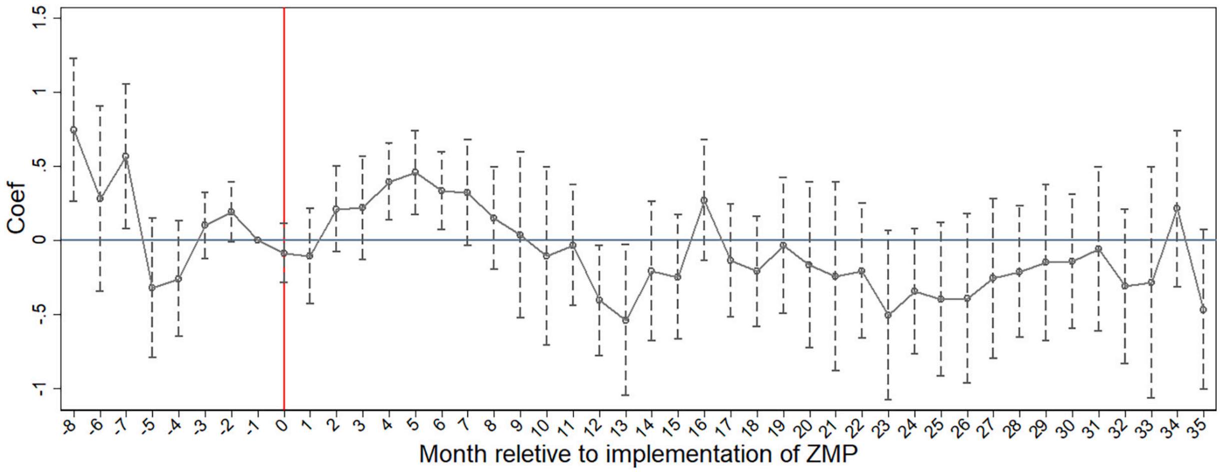

Fig. A2. Parallel trends of Chinese patent medicine expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP.

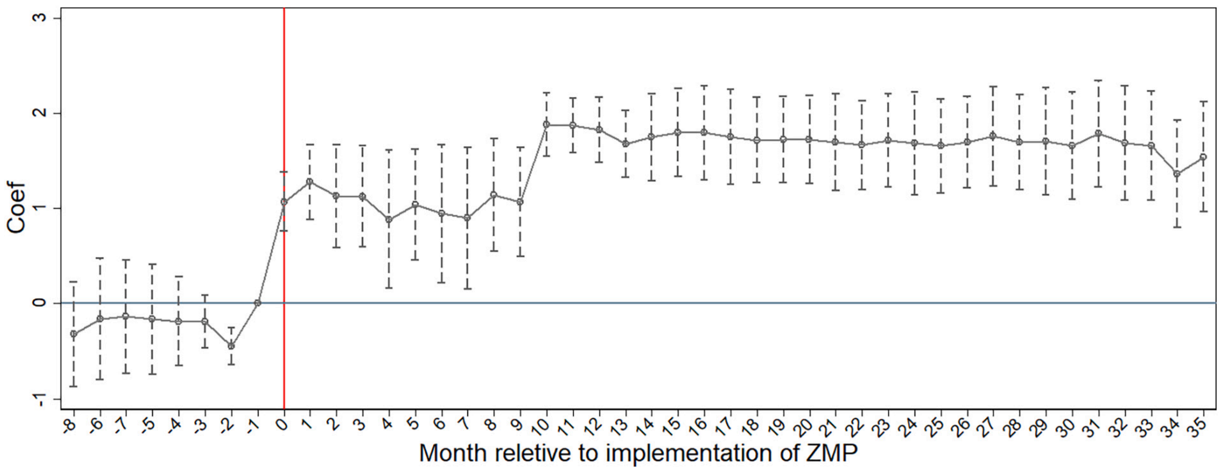

Fig. A3. Parallel trends of medical examination and treatment expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP. (c) The medical examination and treatment expenses began to increase because fees for medical services are included in this category.

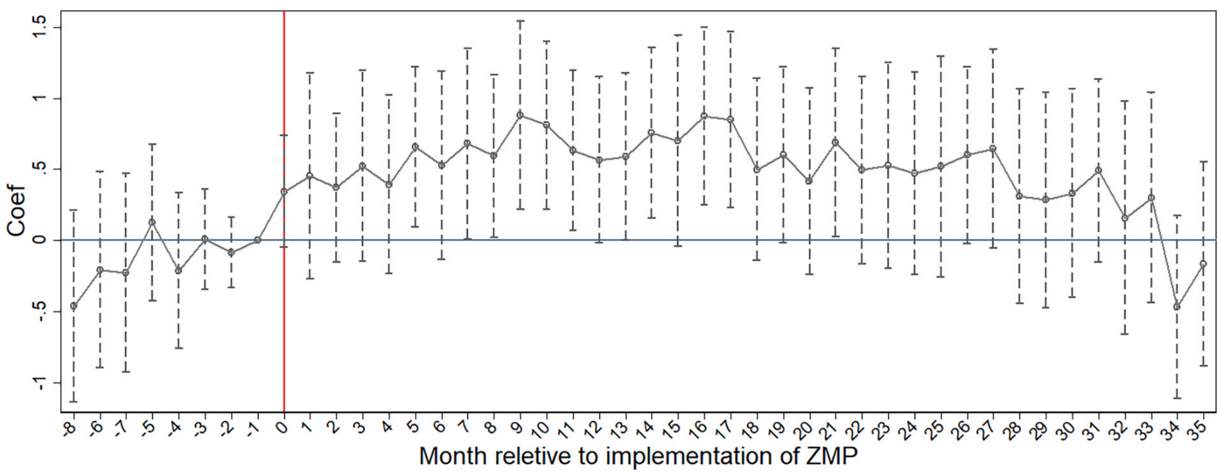

Fig. A4. Parallel trends of nursing expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP.

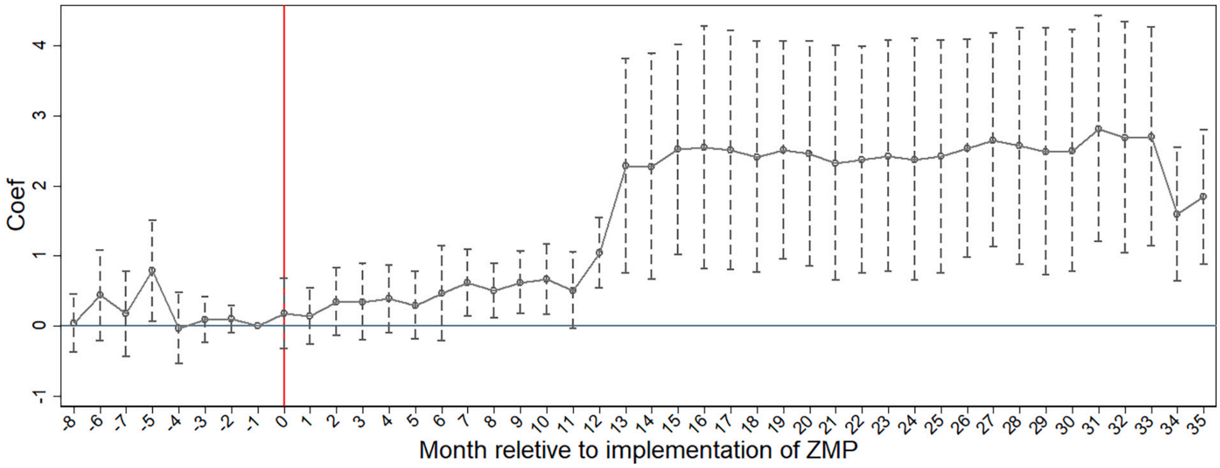

Fig. A5. Parallel trends of general treatment expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP.

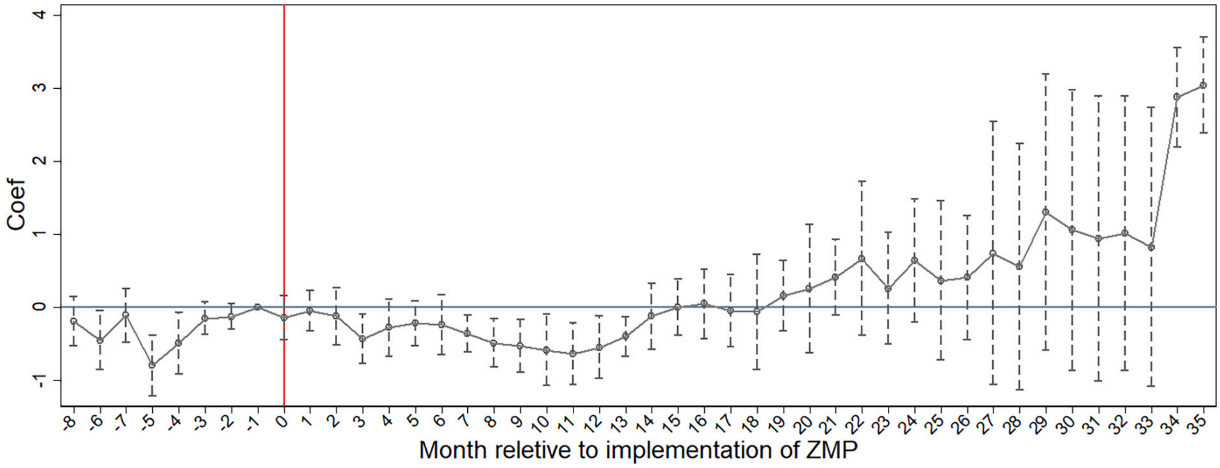

Fig. A6. Parallel trends of disposable medical materials expenses.
Note: (a) Pre and post are defined at the month level. (b) The benchmark period is the month before implementation of the ZMP.

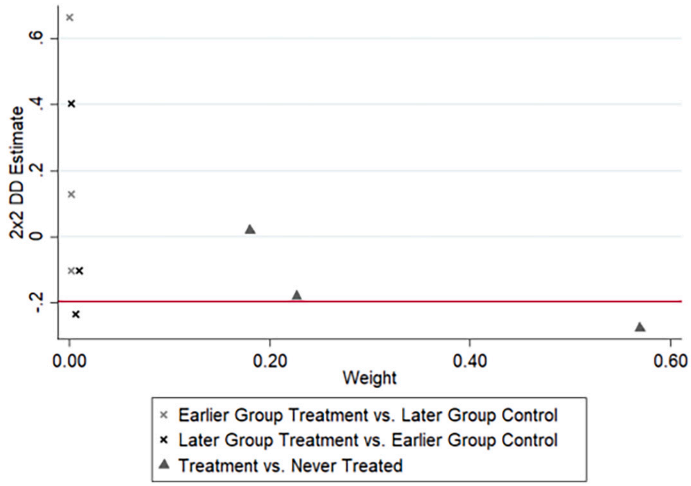

Fig. A7. Decomposition of two-group comparisons.
Note: (a) The red line is the weighted average effect of the ZMP.

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