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Can public hospital reform reduce medical resource mismatches? Evidence from China

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Abstract

Background The mismatch of medical resources is a significant issue in global healthcare, undermining both service accessibility and system efficiency. In China, despite the implementation of the "Healthy China" strategy, persistent mismatches remain due to factors such as industrialization, urbanization, and population aging. This study empirically evaluates the impact of Public Hospital Reform (PHR) on mitigating these mismatches.

Methods A Difference-in-Differences (DD) approach is applied to panel data from 300 cities spanning 2010 to 2021, using the phased implementation of PHR as a quasi-natural experiment. This allows for a comparative analysis of changes in resource allocation between cities that adopted the reform and those that did not. Quantile regression assesses the effects of PHR across varying levels of resource mismatch, while mechanism tests investigate how PHR influences mismatches through cost reduction and supply expansion.

Results PHR is found to reduce medical resource mismatches by 13.9%, primarily driven by cost reductions and increased resource supply. The effects are more pronounced at both lower and higher levels of mismatch, with a limited impact at mid-levels. Furthermore, the reform's effectiveness diminishes as it is extended to more cities, suggesting a potential saturation effect.

Conclusions This study demonstrates that PHR significantly alleviates medical resource mismatches in China. The findings underscore the need to focus on cost control and resource supply in future healthcare reforms, providing key insights for policymakers in developing countries facing similar healthcare resource challenges.

Keywords Mismatched medical resources, Public Hospital Reform, Cost effect, Supply effect

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Introduction

The allocation of medical resources is a fundamental issue in global health policy [1]. The problem of mismatched medical resources has persisted over time, exhibiting characteristics such as universality, persistence over the long term, and global prevalence [2]. As the world's second-most populous country, China has implemented the "Healthy China" strategy to facilitate the rapid expansion and optimization of medical resources. However, significant mismatches remain, leading to difficulties and high costs for the general population when accessing medical care. Major public health emergencies like the COVID-19 pandemic have further highlighted both global and national challenges in medical resource allocation. Therefore, exploring methods to reduce the mismatch of medical resources is of significant practical importance [3, 4].

In most countries, public hospitals serve as the primary providers of medical services, and the public nature and externalities associated with medical resources necessitate government involvement in resource allocation [5]. Public hospitals play a central role in allocating medical resources and are crucial to the overall development of the healthcare system, determining both the quality and efficiency of healthcare services. Many countries, including several in Europe, have targeted public hospitals for reform, aiming to alleviate resource mismatches. For instance, Norway implemented a Public Hospital Reform (PHR) in 2002, with the goal of ensuring the availability, quality, and fair distribution of medical resources, while Turkey's 2003 healthcare reform enhanced resource utilization within public hospitals [6–8]. In the case of China, influenced by factors such as industrialization, urbanization, and an aging population, the healthcare sector has struggled to meet the growing demands of its population, exacerbating resource shortages and mismatches [9].

The analysis suggests that public hospital reforms (PHR) are crucial in addressing medical resource mismatches by optimizing their allocation within the healthcare system. Public hospitals, as the main providers of medical services in China, employ 64% of doctors, provide 82% of inpatient services, and manage 40% of outpatient services [10]. Given this central role, PHR significantly influences the overall distribution of medical resources and is directly associated with reducing healthcare resource mismatches. However, despite the important role of PHR, existing research has primarily focused on qualitative perspectives, discussing improvements in resource distribution and service quality while lacking rigorous empirical evidence to support the causal relationship between PHR and the reduction in medical resource mismatches [11–13].

To address the gap in empirical research on the relationship between PHR and medical resource mismatches, this study employs a rigorous methodological approach. The research utilizes the Difference-in-Differences (DD) method by leveraging the phased implementation of PHR across Chinese cities as a quasi-natural experiment. Using balanced panel data from 300 cities covering the period 2010 to 2021, the study aims to rigorously assess the causal impact of PHR on the mismatch of medical resources. The DD method allows for the comparison of changes in resource allocation between cities that implemented PHR and those that did not, while controlling for confounding factors. In addition, mechanism tests are conducted using the three-step method to identify the specific channels through which PHR affects the mismatch of medical resources, such as through cost reduction and supply expansion.

Current studies on the mismatch of medical resources and public hospital reforms primarily adopt a qualitative approach, discussing how PHR may improve the allocation of human resources and the quality of medical services. However, these studies lack empirical evidence to quantify the causal effect of PHR on medical resource mismatches. Additionally, existing research has primarily focused on developed countries, while evidence from developing nations, particularly China, remains limited. Without rigorous empirical data, the actual mechanisms through which PHR affects the mismatch of medical resources remain unclear, leaving a significant gap in the literature that this study aims to address [12, 14].

This study presents three potential marginal contributions. First, from a theoretical perspective, it introduces an innovative framework based on Institutional Theory and Human Capital Theory, elucidating how PHR influences the mismatch of medical resources through cost effects and supply effects. This framework offers a new lens for theoretical discussions in the relevant field. Second, in terms of empirical analysis, the study employs a rigorous causal identification framework to verify the causal relationship between PHR and the mismatch of medical resources, thereby addressing a gap in quantitative research. Lastly, from a policy application standpoint, it highlights the heterogeneous effects of PHR at different levels of resource mismatch, providing practical policy recommendations for optimizing public hospital reform.

The remaining structure of this study is organized as follows: Sect. 2 reviews the background of PHR and the relevant literature. Section 3 presents the hypotheses to be tested through theoretical analysis. Section 4 outlines the research design. Section 5 presents basic regression analysis. Section 6 explores potential mechanisms. Section 7 performs heterogeneity analysis. Section 8 concludes with policy recommendations.

Policy background and literature review

The PHR Policy

The reform and opening up of China in the late 20th century represents one of the most significant events in world history, while healthcare stands as a critical livelihood issue and a fundamental driving force, as well as an ultimate goal, of economic development. Healthcare reform is a crucial component of China's broader reform and opening-up strategy [15]. Since the early 1990s, public hospitals in China have actively pursued reforms aimed at adjusting and improving internal operating mechanisms, seeking to achieve unified allocation and sharing of medical resources, strengthen hospital management, reduce operating costs, and enhance service efficiency [16]. However, due to certain shortcomings, the predetermined goals were not fully realized, and only partial progress was achieved during the reform process [17].

In 2009, the Chinese government issued the "Opinions of the CPC Central Committee and the State Council on Deepening the Reform of the Medical and Health Care System," which clarified the guiding principles, overall objectives, basic framework, and policy measures for the future of healthcare reform in China, thereby officially launching a new round of reforms. Public hospitals represent a concentrated reflection of the development of the healthcare sector, and the achievements of healthcare reform must be consolidated through PHR. PHR is a central focus of public attention and serves as a key indicator of the direction of healthcare reform [18].

Therefore, in February 2010, the Chinese government announced the first batch of national PHR pilot cities, selecting 16 cities, including Anshan City, to take the lead in implementing PHR. In February 2011, further guidance standards were introduced to adjust the allocation of medical resources and the layout of public hospitals according to different regional types, strictly control public hospital construction, and optimize medical resource allocation [19]. In July of the same year, Beijing was designated as a national PHR pilot city. In April 2014, the pilot scope of PHR was expanded, requiring each province to have at least one national PHR pilot city, resulting in the selection of 17 cities, including Tianjin, as the second batch of national PHR pilot cities. In May 2015, the General Office of the State Council recommended accelerating the promotion of PHR, fully leveraging the public welfare role of public hospitals and optimizing the layout of medical resources [20]. In line with the goal of piloting PHR in more than 100 cities at or above the prefecture level, all cities in the pilot provinces meeting this criterion were included, resulting in 66 cities, including Benxi, being selected as the third batch of national PHR pilot cities. In May 2016, 100 additional prefecture-level administrative regions, including Jinzhou, were designated as the fourth batch of national PHR pilot cities, bringing the total number of PHR pilot cities in China to 200.

In April 2017, based on consolidating and improving PHR of the first four pilot cities, especially on the reform model of Sanming City, comprehensive reforms were initiated in public hospitals. In May 2021, the General Office of the State Council proposed accelerating the expansion of high-quality medical resources and promoting a more balanced regional distribution. It also aimed to shift the development model of public hospitals from scale expansion to quality improvement and efficiency enhancement, and to reorient resource allocation from a focus on material elements to a greater emphasis on talent and technical expertise [21]. This would provide strong support for providing high-quality and efficient medical services, preventing and mitigating major epidemics and public health risks, and building a healthier China. In April 2022, the government announced 15 PHR and high-quality development demonstration project cities, represented by Sanming City, which received support from the central government. In April 2023, another 15 cities, represented by Beijing, were announced. Chinese PHR has entered a new stage of high-quality development.

PHR and the mismatch of medical resources

Medical resources refer to the various production factors consumed or used in the process of providing medical services, including medical human resources, medical material resources, and medical financial resources. The mismatch of medical resources is the inability to distribute medical resources reasonably and effectively in order to meet societal demands. The goal of the new medical reform is to allocate medical resources rationally and make more full use of them [22]. PHR requires the development of national guidelines for the allocation of medical resources in different regions to optimize the allocation of medical resources nationwide and reduce mismatches [19]. Guo et al. (2023) believe that public hospitals, as important carriers for the distribution of medical resources, are crucial nodes for improving the mismatch of medical resources [23]. Zhang et al. (2022) propose that the strategy of PHR is mainly to optimize the allocation of production factors in resources layout, technological innovation, and other aspects, which is the most effective way to optimize the mismatch of medical resources in the short term [24]. Cai et al. (2023) argue that PHR is of great significance in improving the mismatch of medical resources by optimizing the allocation of human resources in public hospitals, enhancing the enthusiasm of medical personnel and improving the supply capacity of high-quality medical services [11]. Zhu and Song (2022) have shown in their research that during PHR, medical resources were utilized more fully and effectively, and their configuration was significantly improved [25].

Impacts of PHR

China's public hospital resources account for 95% of all medical resources, and this monopoly combined with a market-oriented approach exacerbates the mismatch of medical resources, which must be addressed through reform [26]. In 2009, China launched a new medical reform plan aimed at providing affordable and equitable basic medical services to the people by 2020. The aim was to fundamentally change the long-standing shortage of medical resources and reverse the profit-oriented behavior of public medical institutions. Therefore, PHR is an important component of this health care reform [27]. Studies have shown that PHR has a positive impact on hospital operational efficiency, internal management, overall resources allocation and social benefits, with initial reform effects [11, 28–30].

Influencing factors on mismatch of medical resources

The mismatch of medical resources is not caused by a single factor, but by a combination of multiple factors. Firstly, economic development has a significant impact on the allocation of medical resources. Economic growth can promote the efficiency of medical resources allocation and better distribute medical resources for health services. However, in economically underdeveloped areas, due to insufficient technology and talent, the efficiency of medical resources allocation is low and the quality of medical services is inadequate [31, 32]. Secondly, population and industrial structure are one of the main factors affecting the mismatch of medical resources. The adjustment of industrial structure can easily lead to lower fertility rates and higher migration rates, indirectly affecting the distribution of medical resources [33]. At the same time, topography and landscape can also affect the mismatch of medical resources. In areas with rugged terrain and inconvenient transportation, medical resources and facilities are relatively scarce, making the mismatch of medical resources more likely [4]. Finally, urbanization rate, government intervention, per capita GDP, and population density all have a certain impact on the allocation of medical resources, which may cause resources mismatch [34].

Theoretical analysis and hypothesis

In this section, we develop a systematic theoretical framework to comprehensively explore the impact of PHR on the mismatch of medical resources. This framework is primarily based on two theories: **Institutional Theory** and **Human Capital Theory**.

From the perspective of **Institutional Theory**, PHR is not merely a policy intervention but a process of institutional restructuring within the healthcare system. By optimizing resource allocation, PHR enhances the efficiency of public services and ensures the rational distribution of medical resources to meet evolving demands, thereby promoting the sustainable development of the healthcare system. **Human Capital Theory** emphasizes the central role of human resources in the healthcare system. By increasing the quantity and improving the quality of healthcare personnel, PHR effectively enhances the efficiency of medical resource utilization, leading to improved overall health outcomes. This investment not only increases the accessibility of healthcare services but also provides patients with higher quality care, ultimately contributing to the overall health of society.

Based on this integrated theoretical framework, we propose the core hypothesis that PHR effectively reduces the mismatch of medical resources and further investigates its specific mechanisms through cost and supply effects. This study will provide important theoretical foundations and empirical support for understanding the role of PHR in optimizing the allocation of medical resources.

Basic hypothesis

In China's healthcare system, public hospitals serve as the backbone, bearing the critical responsibility of safeguarding the health of the population [35]. PHR is a strategic initiative aimed at establishing clear divisions of labor and optimizing resource allocation, becoming a central component of nationwide healthcare reform [36]. According to **Institutional Theory**, PHR is not merely a policy intervention but a process of institutional restructuring within the healthcare system. By optimizing resource allocation, it enhances the efficiency of public services and ensures the rational distribution of medical resources to adapt to the evolving societal demands.

From the perspective of **Human Capital Theory**, PHR underscores the central role of human resources in the healthcare system. By increasing the number of healthcare personnel and improving their professional qualifications, PHR effectively enhances the efficiency of medical resource utilization and improves overall health outcomes. Such investment not only increases the accessibility of healthcare services but also provides patients with higher quality care [37].

Since the implementation of PHR, studies indicate an improvement in the mismatch of medical resources in China, reflecting the government's efforts to narrow the healthcare service gap between different regions and populations. Thus, PHR is not only a cornerstone of healthcare reform but also a crucial tool for improving resource allocation and promoting health equity. Based on this theoretical framework, we propose the following core hypothesis:

Hypothesis 1 PHR reduces the mismatch of medical resources.

Mechanism hypothesis

Before the implementation of PHR, China's healthcare system exhibited significant pricing imbalances, characterized by a substantial underestimation of basic medical service prices while advanced medical equipment costs were excessively high. This led to a revenue structure in public hospitals that heavily relied on drug sales and the utilization of medical devices, undermining the professional value of healthcare human resources and resulting in inefficient resource allocation that contributed to rising healthcare costs [38].

PHR aims to address these inefficiencies by optimizing the allocation of medical resources to enhance both the efficiency and quality of healthcare services, particularly in the areas of medical treatment and pharmaceuticals, which consume substantial resources [39]. PHR promotes the use of primary healthcare services and restructures compensation mechanisms within public hospitals to control costs, reduce dependency on drug sales, and ensure that the value of healthcare human resources is adequately recognized [40]. This aligns with **Human Capital Theory**, which posits that investing in human resources can enhance the overall efficiency of healthcare services, thereby creating greater value for the entire healthcare system [41].

Additionally, PHR has implemented a series of measures to alleviate the mismatch of medical resources across regions and income groups. By lowering the costs of medical resources and adjusting the relative pricing of treatments, PHR aims to achieve a more equitable and efficient distribution of resources. This approach is consistent with **Institutional Theory**, which emphasizes optimizing resource allocation through institutional restructuring to facilitate the stable and efficient operation of public hospitals. Through these reforms, PHR not only opens new avenues for controlling healthcare costs but also alleviates the financial burden on patients, ensuring that diverse groups can access high-quality healthcare services more equitably.

Based on these theoretical insights and empirical evidence, we assert that PHR effectively mitigates the mismatch of medical resources through its cost-reduction mechanisms. Therefore, we propose the following hypothesis:

Hypothesis 2a PHR mitigates the mismatch of medical resources through the cost effect.

In China, PHR has played a critical role in expanding the supply of medical resources, significantly enhancing the overall efficiency and accessibility of healthcare services. From the perspective of **Human Capital Theory**, the increase in healthcare personnel is viewed as a vital component of human capital that directly impacts health outcomes. High-quality healthcare providers not only deliver superior medical services but also improve the overall patient experience [42]. This enhancement of human resources helps to increase the accessibility of healthcare services, ensuring that more patients can receive timely medical care, thereby effectively reducing health risks associated with resource shortages.

Simultaneously, **Institutional Theory** emphasizes the importance of the institutional environment in resource allocation. PHR systematically restructures the mechanisms for distributing medical resources, promoting rational allocation and efficient utilization [43]. This institutional transformation not only optimizes the supply chain of medical resources but also enhances the coordination and transparency of healthcare services. By establishing clear responsibilities and accountability mechanisms, PHR effectively guides medical resources toward areas with more urgent needs, alleviating the mismatch of resources and ensuring that all populations can access necessary healthcare services.

The expansion of medical resource supply also promotes equity in resource distribution. Within the framework of institutional reform, PHR aims to reduce disparities in resource allocation between regions and income groups, ensuring that all demographics can equitably access healthcare services. This equity not only contributes to improving the overall health level of society but also enhances public trust in the healthcare system, thus increasing the operational efficiency and sustainability of the entire healthcare system.

In summary, from a theoretical perspective, PHR significantly enhances the supply of medical resources and promotes the efficiency and equity of healthcare services, effectively addressing the issue of resource mismatch. Based on these theoretical insights, we propose the following hypothesis:

Hypothesis 2b PHR reduces the mismatch of medical resources through the supply effect.

Study design

Data sources

The data for this study were mainly obtained from the official website of the National Bureau of Statistics of China, provincial statistics yearbooks, city statistics yearbooks, city construction statistics yearbooks, China health statistics yearbooks and statistical annual reports on the development of health programs in past years. For missing data in certain cities and years, we manually searched official channels such as local government websites and reports to supplement the information. Considering data availability and to eliminate potential impacts from exogenous policy shocks such as the 2008 global financial crisis and the largest-ever corporate income tax reform, we ultimately obtained a balanced panel dataset covering 300 cities from 2010 to 2021, with a total of 3,600 observations. To prevent the influence of outliers, we conducted 1% winsorization on all continuous variables.

Perturbation equation

Following the approach of Njuho and Milliken (2009) [44], we constructed the following TWFE-DD model:

$$Mismatch_{jt} = \beta_0 + \beta_1 PHR_{jt} + X'\theta + \mu_j + \delta_t + \varepsilon_{jt} \quad (1)$$

where $\mathrm{Mismatch_{jt}}$ represents the degree of mismatch of medical resources in city j in year t; $\mathrm{PHR_{jt}}$ is a virtual variable for public hospital reform; $\mathrm{X}'\theta$ is a series of control variables at the city level to control for the effects of other factors; μ_{j} is the fixed effect of the city to control for unobservable factors that vary only with the city; δ_{t} is the fixed effect of the year to control for unobservable factors that vary only with time; and $\varepsilon_{\mathrm{jt}}$ is the random disturbance term. The coefficient of interest in this study is β_1, which is expected to be significantly negative, indicating that PHR has significantly reduced the degree of mismatch of medical resources in cities.

Variables definition

The dependent variable in this study is the mismatch of medical resources. Hsieh and Klenow (2009) argue that in cases of resources mismatch, factor prices vary across firms, which distorts the resources input ratio in the production process and leads to overall output and efficiency losses [45]. Following their research, we calculated the degree of the mismatch of medical resources at the city level, and the specific process for calculating it is as follows:

$$\begin{aligned} Mismatch_{jt} &= (1+\tau_{kjt})^{\alpha_j}(1+\tau_{ljt})^{\beta_j} \\ &= \left(\frac{(\sigma-1)\alpha_j P_{jt}Y_{jt}}{RK_{jt}\sigma}\right)^{\alpha_j}\left(\frac{(\sigma-1)\beta_j P_{jt}Y_{jt}}{\omega L_{jt}\sigma}\right)^{\beta_j} \end{aligned} \quad (2)$$

In Eq. (2), τ_{kjt} represents the degree of medical capital mismatch in city j in year t, with higher values indicating more distorted marginal output of capital; τ_{ljt} represents the degree of medical labor mismatch in city j in year t, with higher values indicating more distorted marginal output of labor; α_{j} and β_{j} respectively represent the output elasticity of medical capital and medical labor in the city, and $\alpha_{\mathrm{j}} + \beta_{\mathrm{j}} \neq 1$. We estimated this using the Olley and Pakes (1996) method [46]; σ represents the substitution elasticity of output between different cities. Broda and Weinstein (2006) found that this value generally falls within the range of 3 to 10 [47]. To obtain a conservative estimate, we followed Wang et al. (2014) and set $\sigma = 3$ [48]; R represents the cost of capital use, which we set to 0.1 following Hsieh and Klenow (2009) [45]; $P_{jt}Y_{jt}$ represents medical spending in the city, measured using total health care expenditure; ωL_{jt} represents medical labor income in the city, measured using the average income of the medical industry in city j; L represents the number of medical personnel in the city; and K_{jt} represents the amount of medical capital in the city, measured using the total number of hospitals and beds in the city [49]. For ease of interpretation, we took the logarithm of the calculated results, resulting in our dependent variable, the mismatch of medical resources (Mismatch).

Core independent variable. Based on the promotion process of PHR pilot cities in China, 16 pilot cities were identified in 2010, one pilot city was added in 2011, 17 pilot cities were added in 2014, 66 pilot cities were added in 2015, 100 pilot cities were added in 2016, and full-scale promotion began in 2017. According to the mainstream setting method, if a city implements PHR in the first half of year t, then years t and beyond are assigned a value of 1, and other years are assigned a value of 0; if a city implements PHR in the second half of year t, then year t+1 and beyond are assigned a value of 1, and other years are assigned a value of 0. Finally, we get the Core independent variable of this study, PHR.

Control variables. To minimize bias due to omitted variables, based on existing research and actual conditions [50–54], nine variables were selected as control variables for economic level, government intervention, population structure, population density, urbanization rate, open degree, infrastructure construction, industrial structure, and terrain fluctuation: (1) Economic level. The allocation of regional medical resources is mainly based on current economic level and administrative relations because medical resources are non-material labor products that are produced and consumed synchronously [33]. This study uses "per capita GDP" to measure economic level; (2) Government intervention. Government intervention is an important reason for resources mismatch, and fair allocation of medical resources requires government leadership to establish specific standards for resources allocation [55]. This study uses "government fiscal expenditures/regional GDP" to measure government intervention; (3) Population structure. Population structure has an important impact on the allocation of labor force. The "population dividend" optimizes resources allocation efficiency through the flow of labor and the infinite supply of labor offsets the diminishing marginal returns of capital [56]. This study uses "average annual employed population/average annual total population" to measure population structure; (4) Population density. There is a significant positive correlation between human resources density and health outcomes, and mismatch of medical resources can have a negative impact on health outcomes, so regional population density has a significant impact on the allocation of medical resources [57]. This study uses "average annual total population/urban land area" to measure population density; (5) Urbanization rate. The urbanization process directly affects the supply and accessibility of medical resources in cities and improves residents' health conditions and awareness. Therefore, urbanization plays a positive role in improving the efficiency of medical resources allocation and reducing mismatch of medical resources [58].

Table 1 Definition of variables

Variables	Name	Definition
Mismatch	Mismatch of medical resources	As detailed above
PHR	Public Hospital Reform	A city is assigned a value of 1 for the year the policy is implemented and beyond, and 0 for the rest
EconLevel	Economic Level	Log(1 + per capita GDP)
GovExp	Government Intervention	government fiscal expenditures/regional GDP
EmpPop	Population Structure	average annual employed population/average annual total population
PopDensity	Population Density	average annual total population/urban land area
UrbanRate	Urbanization Rate	non-agricultural population/total population
ForeignInvest	Opening degree	actual utilization of foreign capital/ regional GDP
InfraInvest	Infrastructure Construction	fixed asset investment in municipal public facilities construction/regional GDP
TertiaryIndustry	Industrial Structure	output value of the tertiary industry/regional GDP
TerrainVar	Terrain fluctuation	Terrain undulation of the area

[a] Organized by authors

Table 2 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Mismatch	3600	1.008	0.360	0.008	1.520
PHR	3600	0.486	0.500	0.000	1.000
EconLevel	3600	2.481	1.451	0.002	4.999
GovExp	3600	0.264	0.120	0.051	0.469
EmpPop	3600	0.556	0.182	0.238	0.873
PopDensity	3600	0.136	0.078	0.000	0.268
UrbanRate	3600	0.452	0.202	0.103	0.804
ForeignInvest	3600	0.023	0.007	0.007	0.058
InfraInvest	3600	0.023	0.013	0.000	0.046
TertiaryIndustry	3600	0.400	0.278	0.053	0.856
TerrainVar	3600	1.668	1.517	0.003	4.037

[a] Statistics by authors

This study uses "non-agricultural population/total population" to measure urbanization rate; (6) Open degree. The distribution and allocation of medical resources are directly affected by the degree of regional openness [59]. This study uses "actual utilization of foreign capital/regional GDP" to measure open degree; (7) Infrastructure construction. The construction of infrastructure requires a large amount of financial investment, which may have a "crowding out effect" on medical service investment, thus causing mismatch of medical resources [60]. This study uses "fixed asset investment in municipal public facilities construction/regional GDP" to measure infrastructure construction; (8) Industrial structure. The development of the service industry creates conditions for improving the allocation of public resources and guiding population mobility [61]. This study uses "output value of the tertiary industry/regional GDP" to measure industrial structure; (9) Terrain fluctuation. China has a vast land area, and some regions are more restricted by terrain and location, with relatively limited space for living and production, forming a pattern of medical resources allocation that is different between per capita and per unit of land, leading to mismatch of medical resources [62]. This study uses "terrain undulation of the region" to measure terrain fluctuations. As shown in Table 1.

Descriptive statistics

Table 2 below demonstrates the statistical characteristics of the main variables in this study: the mean value of Mismatch is 1.008, and the standard deviation is 0.36, indicating that the current mismatch of medical resources in China is high and fluctuates, similar to the results of Zhang et al. (2023) [63]. The mean value of PHR is 0.486, which means that the treatment group accounts for 48.6% of the total sample, indicating that the treatment group and the control group have a high balance in terms of numbers. Descriptive statistics of other variables are as follows and will not be repeated.

Regression analysis

The previous section presented the theoretical analysis and a set of hypotheses to be tested. In this section, we will empirically test the Hypothesis 1.

Basic regression

Based on Eq. (1) and using a stepwise regression approach, the specific results are shown in Table 3: In column (1), we directly regress *Mismatch* on PHR, and the coefficient is -0.187, significant at the 1% level. This indicates that PHR reduces the mismatch of medical resources by 18.7%. However, this result only reflects the correlation between the two variables and does not control for other factors, which may lead to omitted variable bias. In column (2), we further include control variables, and the coefficient is -0.186, still significant at the 1% level. This suggests that PHR reduces the mismatch of medical resources by 18.6%, with a slight decrease in the effect. In column (3), we further control for unobserved shocks in different years, and the coefficient is -0.158, significant at the 1% level. This indicates that PHR reduces the mismatch of medical resources by 15.8%, with a substantial decrease in the effect. In column (4), we further control for heterogeneity across different cities, and the coefficient is -0.139, significant at the 1% level. This shows that PHR reduces the mismatch of medical

Table 3 Basic regression results

Variables	(1)	(2)	(3)	(4)	(5)
	Mismatch	**Mismatch**	**Mismatch**	**Mismatch**	**Mismatch**
PHR	-0.187***	-0.186***	-0.158***	-0.139***	-0.139***
	(0.0119)	(0.0118)	(0.0204)	(0.0246)	(0.0249)
EconLevel		-0.0101**	-0.0103**	-0.00921**	-0.00921**
		(0.00405)	(0.00406)	(0.00418)	(0.00392)
GovExp		-0.0162***	-0.0166***	-0.0150***	-0.0150***
		(0.00490)	(0.00491)	(0.00502)	(0.00491)
EmpPop		-0.108***	-0.110***	-0.0938***	-0.0938***
		(0.0324)	(0.0324)	(0.0334)	(0.0339)
PopDensity		-0.0155**	-0.0162**	-0.0220***	-0.0220*
		(0.00729)	(0.00729)	(0.00755)	(0.0130)
UrbanRate		-0.120***	-0.117***	-0.0927***	-0.0927***
		(0.0290)	(0.0290)	(0.0299)	(0.0292)
ForeignInvest		-0.0275***	-0.0265***	-0.0254***	-0.0254***
		(0.00867)	(0.00868)	(0.00899)	(0.00907)
InfraInvest		0.109**	0.112**	0.0918**	0.0918**
		(0.0448)	(0.0449)	(0.0462)	(0.0458)
TertiaryIndustry		-0.0497**	-0.0494**	-0.0526**	-0.0526**
		(0.0212)	(0.0212)	(0.0220)	(0.0214)
TerrainVar		0.00688*	0.00678*	0.00669*	0.00669*
		(0.00388)	(0.00390)	(0.00402)	(0.00380)
City FE	N	N	N	Y	Y
Year FE	N	N	Y	Y	Y
Controls	N	Y	Y	Y	Y
Robust	N	N	N	N	Y
Observations	3,600	3,600	3,600	3,600	3,600
R-squared	0.064	0.084	0.088	0.085	0.085

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; City FE stands for city fixed effects to control for the effect of heterogeneity across cities; Year FE stands for year fixed effects to control for the effect of heterogeneity across years; Controls stands for a set of control variables; Robust stands for the use of robust standard errors to control for the effect of heteroskedasticity in the error term

resources by 13.9%. According to publicly available data from the National Bureau of Statistics, government healthcare expenditures increased from 573.249 billion RMB in 2010 to 2.067606 trillion RMB in 2021, averaging 1.336493 trillion RMB over the period. Based on this, we estimate that PHR could result in average savings of 101.306 billion RMB in healthcare costs (1.336493 trillion * 0.0758). In column (5), we use robust standard errors to account for heteroscedasticity in the error term. The coefficient remains unchanged, but the standard errors slightly increase. These regression results support the first hypothesis. In the following analysis, we will consider the results from column (5) as the benchmark regression results.

The baseline regression results indicate that PHR reduces medical resource misallocation by around 13.9%. This finding contrasts with existing literature. Most prior studies focus on policy discussions related to public hospital reform and its qualitative effects on medical resource allocation. For example, Zhu and Song (2022) suggest that PHR has the potential to improve hospital operational efficiency and reduce resource waste [25]. However, these studies often lack systematic quantitative evidence, particularly concerning the empirical analysis of policy effects. This study applies a DD model with panel data from 300 Chinese cities spanning 2010 to 2021, offering more rigorous quantitative evidence that PHR significantly reduces medical resource misallocation. Moreover, official statistics estimate that PHR could save around 101.306 billion RMB annually in medical costs, further confirming its practical impact on policy implementation and addressing the quantitative research gap in the literature.

Now let's examine the effects of the control variables, which are generally consistent with our expectations: EconLevel has a coefficient of -0.00921 on Mismatch, indicating that an increase in economic level significantly reduces the mismatch of medical resources. GovExp has a coefficient of -0.0150, indicating that government intervention alleviates the mismatch of medical resources. EmpPop has a coefficient of -0.0938, suggesting that an increase in the number of health care workers reduces the mismatch of medical resources. PopDensity has a coefficient of -0.022, indicating that higher population density is associated with lower levels of the mismatch of medical resources. UrbanRate has a coefficient of -0.0927, indicating that an increase in urbanization rate significantly reduces the mismatch of medical resources. ForeignInvest has a coefficient of -0.0254, suggesting that a higher degree of openness is associated with lower levels of the mismatch of medical resources. InfraInvest has a coefficient of 0.0918, indicating that infrastructure development exacerbates the mismatch of medical resources. TertiaryIndustry has a coefficient of -0.0526, suggesting that an increase in the proportion of the tertiary industry alleviates the mismatch of medical resources. TerrainVar has a coefficient of 0.00669, indicating that greater terrain undulation exacerbates the mismatch of medical resources.

Dynamic test

The premise of using the DD method is that the treatment group and the control group follow parallel trends. Drawing on the event study methodology commonly used in finance, [64] we construct the following dynamic econometric model:

$$Mismatch_{jt} = \beta_0 + \sum_{event=-7}^{event=+5} \beta^{event} PHR_{j,event} + X'\theta + \mu_j + \delta_t + \varepsilon_{jt} \quad (3)$$

In Eq. (3), "event" represents the event period. When the event occurs, we set event=0. In the period before the event, we set event = -1. In the period after the event, we set event=+1. The interpretation of other variables is the same as in Eq. (1) and will not be repeated. The specific regression results are shown in Fig. 1: When event<0, none of the regression coefficients are significant, indicating that there is no significant difference between the pilot cities and non-pilot cities before the implementation of PHR, which aligns with the parallel trends assumption. In the period when PHR is implemented (event=0), there is a significant decrease in the mismatch of medical resources. As the event period progresses, the policy effect gradually weakens.

Placebo test

Regarding the baseline regression results of this study, a potential concern is that the random grouping of pilot cities and non-pilot cities may have driven the results,

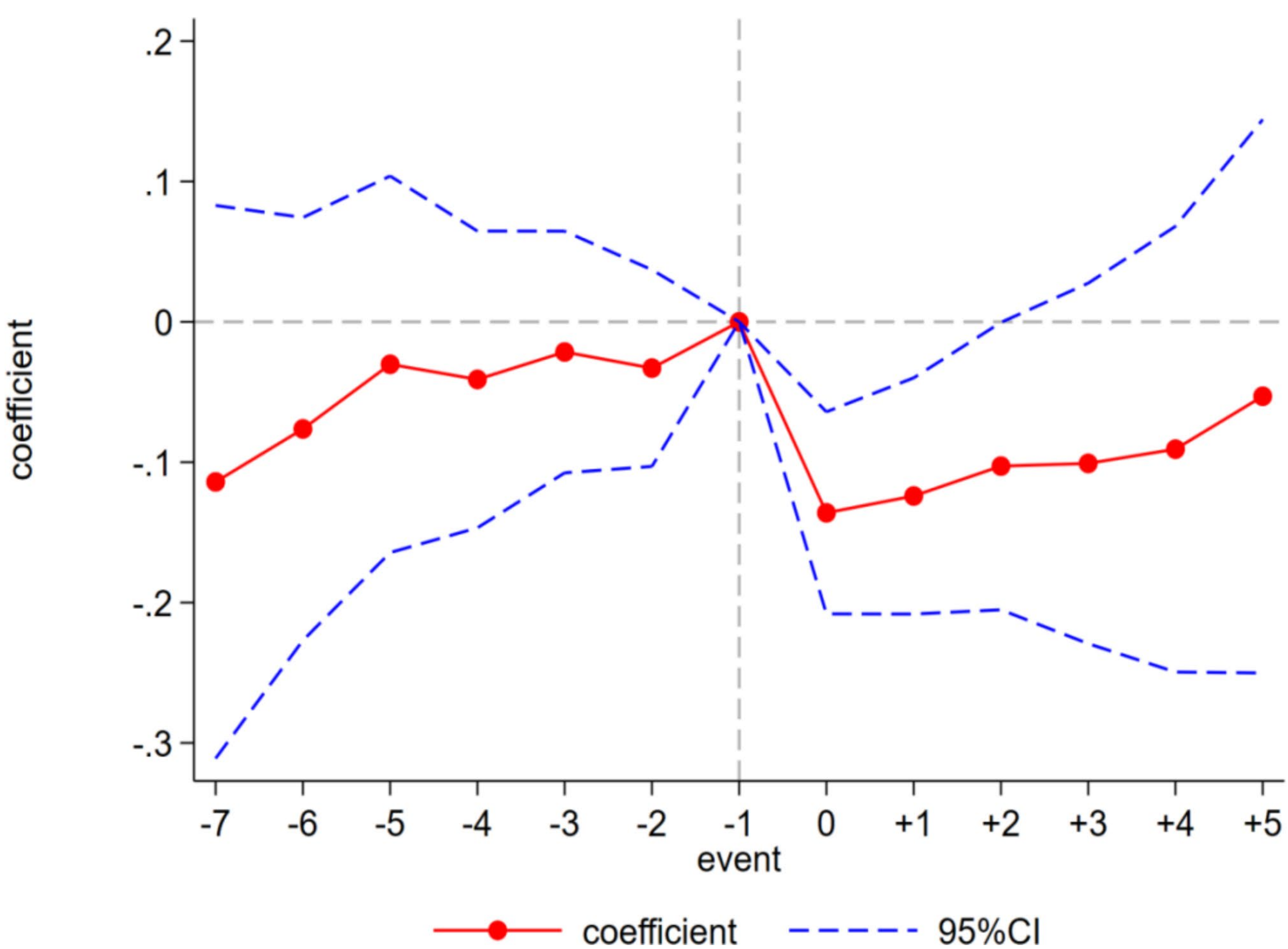

Fig. 1 Dynamic inspection

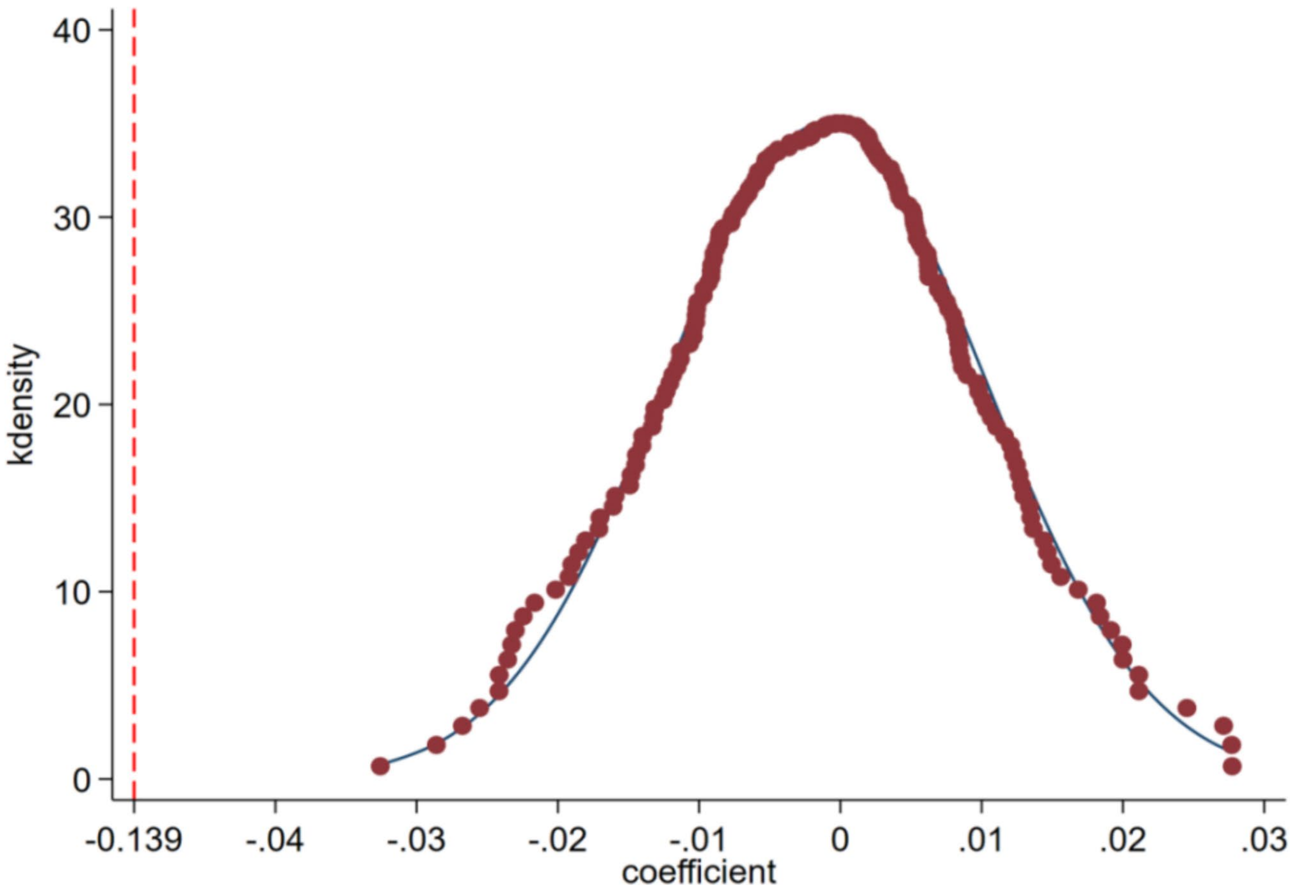

Fig. 2 Placebo test

Table 4 Robustness test

Variables	PSM-DD	Bacon	Mismatch_new	Year <= 2017
	(1)	(2)	(3)	(4)
PHR	-0.174***	-0.104***	-0.143***	0.160***
	(0.0155)	(0.0187)	(0.0299)	(0.0268)
City FE	Y	N	Y	Y
Year FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Robust	N	Y	Y	Y
Observations	3600	3600	3600	3600
R-squared	0.0010	N	0.0488	0.0691

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; City FE stands for city fixed effects to control for the effect of heterogeneity across cities; Year FE stands for year fixed effects to control for the effect of heterogeneity across years; Controls stands for a set of control variables; Robust stands for the use of robust standard errors to control for the effect of heteroskedasticity in the error term

rather than the policy effect of PHR. To alleviate this concern, following the approach of Jones and Daly (1995) [65], we randomly assigned pilot cities and non-pilot cities and conducted a placebo regression 200 times. The density plot of the 200 placebo regression coefficients is shown in Fig. 2. If the baseline regression results were indeed driven by random grouping, we would expect to observe more regression coefficients close to or even greater than the baseline regression coefficient. However, the density plot shows that the placebo regression coefficients are mainly concentrated around zero and differ significantly from the baseline regression coefficient (-0.139). This indicates that the baseline regression results of this study are unlikely to be driven by random grouping.

Robustness test

This section will conduct a series of robustness tests to ensure the robustness of the benchmark regression results, as shown in Table 4:

Propensity score matching (PSM) Due to the possibility of systematic biases between pilot cities and non-pilot cities, it is these biases that drive the generation of the basic regression results in this study, rather than the policy effect of PHR. This can lead to unreliable results of the basic regression. PSM is a statistical method applied to observational research data. It compresses multidimensional information into one dimension using propensity scores and then matches individuals based on these scores. This can make the treatment group and control group as similar as possible under given observable covariates, thereby alleviating selection bias in treatment effects. Following the approach of Leuven and Sianesi (2018) [66], we use a 1:1 nearest neighbor matching. The result is shown in column (1): the coefficient of the effect of PHR on Mismatch is -0.174, which means that PHR reduces the mismatch of medical resources by 17.4%. The result remains robust. Furthermore, PSM requires covariate balance, and we have also performed tests for it. The specific results are shown in Appendix A.

Bacon decomposition Since PHR is implemented gradually, the regression model used in this study essentially belongs to staggered DD. The biggest problem of this model lies in assuming that the treatment effects are generally the same across different treatment groups or different periods. However, this assumption is often difficult to achieve. If there is heterogeneity in treatment effects across groups or over time, the TWFE regression may suffer from negative weights [67, 68], which eventually leads to coefficient reversal. To address this concern, we use the Bacon decomposition method for testing. The result is shown in column (2): the coefficient of the effect of PHR on Mismatch is -0.104, which means that PHR reduces the mismatch of medical resources by 10.4%. Compared to the benchmark regression result, there is a significant decrease in the coefficient, indicating the presence of heterogeneous treatment effects. However, the conclusion remains robust. For detailed decomposition results, please refer to Appendix B.

Alternative measurement of mismatch To ensure that the benchmark regression results are not affected by the measurement method of the dependent variable, we assume an alternative elasticity of output of 10 for different cities and use the LP method to measure the output elasticity. We then recalculate the mismatch of medical resources. The regression result is shown in column (3): the coefficient of the effect of PHR on Mismatch is -0.143, which means that PHR reduces the mismatch of medical resources by 14.3%. The result remains robust.

Exclusion of post-implementation years PHR achieved full coverage in April 2017, which means that all samples from 2018 onwards became the treatment group without a control group. To prevent distortion of the results from this portion of the samples, we exclude all samples from 2018 onwards and conduct the regression again. The specific result is shown in column (4): the coefficient of the effect of PHR on Mismatch is -0.16, which means that PHR reduces the mismatch of medical resources by 16%. The result remains robust.

In addition, we also conducted a spatial regression analysis, and the results remained robust, as detailed in Appendix C.

Mechanism test

The previous empirical findings have demonstrated that PHR can significantly reduce the mismatch of medical resources allocation. In this section, we will employ a three-step approach to examine its underlying mechanisms, with specific results presented in Table 5.

Cost effect

Hypothesis 2a in the theoretical analysis posits that PHR reduces the mismatch of medical resources through cost effect. Drawing on the study conducted by Gong and Kang (2023) [69], this study selects the logarithm of fiscal health expenditure (LnCost) as a measure of medical resources costs, using it as the dependent variable in a revised regression analysis. The results shown in columns (1)-(2), indicate that the coefficient of PHR is -0.0758, significant at the 1% level, suggesting a 7.58% decrease in medical resources costs due to PHR. Additionally, column (2) reveals that the coefficient of LnCost on Mismatch is 0.0474, significant at the 5% level, indicating a 4.74% increase in the mismatch of medical resources resulting from rising costs. Overall, these analyses demonstrate that PHR achieves a reduction in the mismatch of medical resources through the mechanism of cost effect, thus confirming **Hypothesis 2a**.

The above analysis indicates that PHR has played a critical role in reducing medical resource mismatches by lowering costs. Prior to the implementation of PHR, public hospitals in China primarily relied on the sale of pharmaceuticals and the use of advanced medical equipment as their main sources of revenue, leading to rising healthcare costs and inefficient resource allocation. PHR aims to optimize resource allocation by reducing reliance on high-cost medical equipment and pharmaceuticals

Table 5 Mechanism test

Variables	LnCost	Mismatch	Supply	Mismatch
	(1)	(2)	(3)	(4)
PHR	-0.0758***	-0.136***	0.0894***	-0.128***
	(0.0215)	(0.0250)	(0.0209)	(0.0249)
LnCost		0.0474**		
		(0.0217)		
Supply				-0.126***
				(0.0191)
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Robust	Y	Y	Y	Y
Observations	3,600	3,600	3,600	3,600
R-squared	0.026	0.086	0.039	0.095

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; City FE stands for city fixed effects to control for the effect of heterogeneity across cities; Year FE stands for year fixed effects to control for the effect of heterogeneity across years; Controls stands for a set of control variables; Robust stands for the use of robust standard errors to control for the effect of heteroskedasticity in the error term and shifting the focus to more cost-effective primary healthcare services. Specifically, PHR has promoted improvements in internal hospital management, facilitated the efficient use of existing resources, and improved compensation mechanisms for medical personnel. These reforms have reduced dependence on expensive equipment and excessive treatment, thus lowering hospital operational costs. However, due to the lack of comprehensive data, we are currently unable to empirically test these specific effects, which represents a promising area for future research.

Supply effect

Hypothesis 2b in the theoretical analysis proposes that PHR reduces the mismatch of medical resources through supply effect. Referring to the research by Wang and Zha [12], this study employs the number of hospitals, beds, and doctors as three indicators to measure the overall quantity of medical resources (Supply). Principal component analysis is used for dimension reduction, and the resulting variables are utilized as the dependent variable in a revised regression analysis. The results shown in columns (3)-(4), indicate that the coefficient of PHR is 0.0894, significant at the 1% level, indicating an 8.94% increase in the total quantity of medical resources due to PHR. Furthermore, column (4) reveals that the coefficient of Supply is -0.126, significant at the 1% level, suggesting a 12.6% decrease in the mismatch of medical resources resulting from an increase in the overall quantity of resources. These analyses collectively demonstrate that PHR achieves a reduction in the mismatch of medical resources through the mechanism of supply effect, thus confirming **Hypothesis 2b**.

The mechanism test results indicate that PHR reduces medical resource misallocation by lowering resource costs (7.58%) and increasing resource supply (8.94%). This study provides more detailed quantitative evidence than existing literature, validating the specific mechanisms by which PHR optimizes resource allocation. Most prior studies rely primarily on qualitative analysis, discussing the potential effects of PHR on improving medical resource allocation efficiency. For instance, Zhang et al. (2022) suggest that PHR reduces resource misallocation by improving hospital management efficiency and optimizing resource distribution, but their work lacks rigorous empirical support [24]. Additionally, Guo et al. (2023) emphasize PHR's importance in resource allocation, noting that it optimizes hospital resource layout and enhances service provision capacity [23]. However, these studies do not systematically quantify PHR's contributions to addressing resource misallocation mechanisms.

The unique contribution of this paper lies in being the first to empirically test, through regression analysis, the specific pathways of PHR's cost and supply effects. Specifically, PHR lowers overall medical resource costs by reducing reliance on high-cost equipment and pharmaceuticals, while optimizing internal hospital management and compensation mechanisms. Additionally, PHR significantly enhances the supply capacity of medical resources by expanding key assets, including hospitals, beds, and medical staff. This extends the existing research framework on PHR's impact on medical resource misallocation. In contrast to previous studies, this paper not only provides quantitative evidence of PHR's effects but also elucidates the specific mechanisms by which it reduces resource misallocation, offering strong support for policymakers.

Heterogeneity analysis

Quantile regression

When examining the impact of PHR on the mismatch of medical resources, quantile regression is effective in revealing the heterogeneous effects of the policy across different levels of mismatch. The study performs quantile regressions at the 5th, 25th, 50th, 75th, and 95th percentiles. The specific results are shown in Panel A of Table 6: PHR has a greater impact at the lower percentiles (5% and 25%), while its effect is insignificant at the median (50%). Although the effect increases again at the higher percentiles (75% and 95%), it is still smaller than at the lower percentiles.

First, the impact of PHR is more pronounced at the lower percentiles, likely due to regions with a lower degree of mismatch having relatively well-allocated medical resources. In these areas, PHR is able to take effect more rapidly by optimizing management and resource distribution. These regions' healthcare systems are already close to the efficiency frontier, leading to greater marginal benefits from the reform. Second, at the median percentile, the impact of PHR is not significant, which is likely attributable to structural bottlenecks in regions with moderate mismatch. Although there is some room for optimization in resource allocation, limitations such as inadequate infrastructure and human resource shortages constrain PHR's ability to significantly reduce mismatch in the short term. Lastly, at the higher percentiles, while the effect of PHR increases again, its magnitude remains smaller than at the lower percentiles. This could be because regions with severe resource mismatch face complex structural problems, such as resource shortages and low management efficiency, that constrain the marginal impact of PHR. Although the reform can bring about noticeable improvements, its impact is relatively limited because of unfavorable initial conditions.

Quantile regression results reveal the heterogeneous effects of PHR across varying levels of resource misallocation. Specifically, PHR demonstrates significant effects in regions with either relatively low or high levels

Table 6 Heterogeneity analysis

	Mismatch				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Panel A: Quantile Regression	5%	25%	50%	75%	95%
PHR	-0.183*	-0.188*	-0.139	-0.168***	-0.173***
	(0.107)	(0.112)	(0.0917)	(0.0575)	(0.0352)
Observations	3,600	3,600	3,600	3,600	3,600
Panel B: Cumulative Policy Effects	≤2012	≤2013	≤2014	≤2015	≤2016
PHR	-0.483***	-0.523***	-0.185*	-0.167***	-0.156***
	(0.0425)	(0.0348)	(0.0980)	(0.0440)	(0.0314)
Observations	900	1,200	1,500	1,800	2,100
City FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Robust	Y	Y	Y	Y	Y

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; City FE stands for city fixed effects to control for the effect of heterogeneity across cities; Year FE stands for year fixed effects to control for the effect of heterogeneity across years; Controls stands for a set of control variables; Robust stands for the use of robust standard errors to control for the effect of heteroskedasticity in the error term

of misallocation, while the effects are less pronounced in regions with moderate levels. This finding is consistent with existing quantitative literature. For example, Zhang et al. (2023) highlight that in regions with severe resource misallocation, government subsidies to public hospitals may have a persistent negative impact on efficiency [70]. Although reforms may yield some improvements, their effects remain relatively limited. However, this study's quantile regression offers additional quantitative evidence that refines the understanding of PHR's policy effects across different levels, particularly emphasizing the more significant marginal effects of reform in regions with low levels of misallocation. In contrast, existing literature has not conducted a similar quantile regression analysis to uncover the heterogeneous effects of reform across different misallocation levels, focusing instead on its overall impact. By quantifying PHR's specific impact across varying misallocation levels, this study provides clearer policy guidance, suggesting that PHR should adopt region-specific strategies to optimize medical resource allocation and improve reform effectiveness.

Cumulative policy effects

When evaluating the long-term effects of public policy, the cumulative effects of the policy often offer a more comprehensive perspective. For PHR, its policy effects may not immediately manifest after implementation but rather gradually accumulate over time. Therefore, it is necessary to consider the impact of PHR on the mismatch of medical resources at various stages, particularly as the reform expands gradually. The marginal effects of the reform may change as more experimental groups are introduced. By analyzing the cumulative effects of the policy, we can obtain a clearer understanding of PHR's long-term impact on the allocation of medical resources and provide a basis for future policy optimization.

To this end, we first examined the policy impact before 2012 and then gradually extended the timeline, adding more experimental cities to assess the cumulative effects of the policy. The specific results are shown in Panel B of Table 6: As time passes and more cities are included in the experimental group, the impact coefficient shows a clear downward trend. This indicates that as the coverage of PHR expands, the policy effects diminish to some degree.

This phenomenon can be explained from the perspective of diminishing marginal returns. In the early stages of the policy, the reform's impact tends to be more significant, especially in a small number of experimental cities where the mismatch of medical resources is more pronounced, enabling PHR to take effect rapidly. As more cities join the reform pilot, the initial impact of the policy gradually fades, and the marginal effects of PHR start to decline. This may be because, in the later stages of implementation, the degree of resource misallocation has been alleviated to some extent, but the remaining mismatch problems are more complex and challenging to resolve through a single policy intervention. Additionally, as the reform expands, the dispersion of resources and regional differences in the implementation process might also contribute to the weakening policy effects.

The results of the cumulative policy effect analysis are consistent with findings in the literature, such as Guo et al. (2023) [23], who observed significant effects during the early stages of PHR implementation. However, as the policy expanded to more cities, the initial reform benefits gradually diminished, and marginal returns declined. This study empirically validates this trend and further identifies that in the later stages of the reform, complex structural issues and regional disparities are likely key factors contributing to the diminishing policy effects. Thus, the cumulative policy effect analysis in this paper offers new quantitative support to the literature, revealing the dynamic relationship between the long-term effects of the reform and its scale of implementation.

In addition, we also conducted a heterogeneity analysis across different regions, economic development levels, and population densities, which is presented in Appendix D.

Conclusions and policy recommendations

This study demonstrates that China's PHR is instrumental in reducing the mismatch of medical resources by 13.9%, primarily through cost reduction and supply expansion mechanisms. By employing a robust DD approach and utilizing comprehensive panel data from 300 cities, this research offers the first rigorous empirical evidence linking PHR to improvements in medical resource allocation. Importantly, the study highlights nuanced impacts through quantile regression, revealing that PHR's effects are more significant at both the lower and upper extremes of resource mismatch but less pronounced in the middle range. Moreover, the cumulative effect analysis indicates that the reform's effectiveness decreases as it is implemented in an increasing number of cities over time. These findings contribute to the literature on healthcare reform by providing greater insight into the mechanisms and varied impacts of PHR.

The empirical findings of this study demonstrate that PHR effectively reduces the mismatch of medical resources. Based on this, the following three policy recommendations are proposed to further optimize resource allocation. **First**, deepening PHR to enhance hospital autonomy and management efficiency. The regression results show that PHR reduces the mismatch of medical resources by 13.9%, indicating a significant policy impact. To consolidate and expand this effect, it is recommended to further increase hospital autonomy in resource allocation, enabling hospitals to flexibly design resource distribution plans, especially across different departments and personnel. By implementing scientifically designed resource allocation strategies, hospitals can better address internal management challenges and improve the quality and efficiency of healthcare services. **Second**, promoting dynamic pricing models and cost control mechanisms for medical resources. The mechanism analysis reveals that PHR reduces the mismatch of medical resources by lowering resource costs. To further amplify this effect, it is recommended to introduce dynamic pricing models that adjust the price of medical resources in real-time based on feedback from hospitals and patients. Additionally, the government should enhance the monitoring and evaluation of medical resource utilization by establishing standardized cost and supply benchmarks, ensuring that healthcare institutions can operate more efficiently in terms of resource use and cost control. **Finally**, designing stratified reform strategies based on regional heterogeneity. The quantile regression results show that PHR has a significant effect in regions with both low and high levels of resource mismatch, while the impact is less pronounced in regions with moderate mismatch. Therefore, it is recommended to implement differentiated reform strategies based on the degree of mismatch in different regions. In regions with lower levels of mismatch, the focus should be on further optimizing resource allocation and improving management efficiency. In regions with higher levels of mismatch, stronger structural reforms are needed to address deeper issues such as weak infrastructure and staff shortages, ensuring the long-term sustainability of PHR.

Although the study presents significant findings, it also has several limitations. **First**, it does not account for external shocks, such as pandemics or economic crises, which could influence medical resource allocation. Future research could explore how these factors interact with PHR. **Second**, the data is restricted to city-level analysis, potentially overlooking intra-city disparities. Incorporating more localized data in future studies could offer a clearer picture. **Third**, the focus is primarily on cost and supply mechanisms, leaving unexamined other potential factors, including technological advancements or institutional quality. Expanding these areas could deepen the understanding of PHR's full impact.

Supplementary Information

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Supplementary Material 1

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Author contributions

Y.C. and L.G. conceived and wrote the original manuscript. Y.L. and S.L. were responsible for manuscript revision and validation. L.Z. and D.C. were responsible for project management, data collection, and proofreading of the manuscript. W.Y. and L.G. supervised the entire process and provided grant support. All authors read and approved the final manuscript.

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Data availability

Data is available from the corresponding author on request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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