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RESEARCH

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Does an innovative case-based payment scheme promote the hierarchical medical system? A tripartite evolutionary game analysis

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Abstract

Background China is striving to promote a hierarchical medical system (HMS) to improve the efficiency of health resource utilization and ensure health equity. An innovative payment scheme named the "Diagnosis-Intervention Package" (DIP) has been developed recently and implemented in 71 pilot cities nationwide. Although the impact of payment reform on medical expenditure and provider behavior has been demonstrated, there is little evidence on whether the reform promotes the HMS.

Methods This study uses evolutionary game theory to formulate a tripartite evolutionary game model involving the local government (LG), superior medical institutions (SMI), and patients in implementing DIP payment reform. We also analyze the stability of each participant's strategy and the sensitivity of parameters.

Results The results show that for LG, the additional social benefits created for other regions are crucial in influencing the evolution of the game system. SMI are more inclined to support the HMS when the proportion of patient reduction under the DIP payment scheme is low. For patients, the perceived medical quality of primary medical institutions (PMI) is the decisive factor in their strategies.

Conclusion The DIP payment scheme is more likely to promote the HMS in regions with an advanced policy framework, abundant medical resources, and high-quality primary medical services. Policymakers need to create effective incentives to boost support for the HMS from each participant. This study provides a feasible methodology for analyzing the impact of payment reforms that can be used in future research.

Keywords Case-based payment reform, Diagnosis-Intervention Package, Hierarchical medical system, Evolutionary game analysis

Introduction

The Chinese government is actively continuing its medical system reform to ensure medical resources benefit all citizens more equitably [1]. In September 2015, the General Office of the State Council issued the "Guiding Opinions on Promoting the Construction of a Hierarchical Medical System (HMS)", aiming to clarify the functional positioning of medical institutions at different levels and enable them to provide services that align with their designated function, and thus improve their service efficiency [2]. However, the outcomes of this

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reform did not meet expectations. In recent years, superior medical institutions (SMI) in China have become overcrowded. In contrast, the utilization rate of primary medical institutions (PMI) has remained low, and the allocation of medical resources has formed an “inverted triangle” pattern [3, 4]. Compared to other resources, medical resources have two distinct characteristics: public welfare nature and information asymmetry [5, 6]. Public welfare nature implies that the government is responsible for ensuring that basic medical services are distributed equitably among the population [7]. However, since China transitioned from a planned economy to a market economy in the 1980s, the government has scaled back its essential financial support for the survival and development of medical institutions. As a result, these institutions became self-financing entities, needing to attract more patients to sustain themselves and pursue potential growth [8, 9]. Information asymmetry means that medical institutions possess a dominant advantage in professional information, leading patients to rely heavily on doctors’ advice for their medical decisions [10]. Since patients cannot accurately evaluate the quality of therapeutic regimes, they are inclined to seek treatment at SMI. For patients, SMI represent higher technical proficiency and authoritative certification [11]. Therefore, the promotion of HMS has encountered great resistance in China. In 2018, China introduced the “Diagnosis-Intervention Package” (DIP), an innovative case-based payment scheme for hospitalization care within a regional global budget. In November 2020, the National Healthcare Security Administration designated 71 cities as the initial pilot cities for implementing the DIP payment scheme, gradually replacing the traditional fee-for-service system [12]. The Chinese government aims to regulate the behavior of healthcare providers directly or indirectly through financial incentives [13]. Although researchers have examined the impact of DIP payment reform on quality of care, expenditure, length of stay, and out-of-pocket (OOP) payments, there is a lack of research on whether the DIP payment scheme promotes the HMS [14–22]. Therefore, this study explores the impact of DIP payment reform on HMS to fill the gap in existing research.

The traditional fee-for-service incentivizes medical institutions to provide excessive services, particularly to patients with minor illnesses. SMI can increase revenue by admitting minor cases and boosting utilization rates [23]. This approach wastes significant medical insurance funds and reduces medical institutions’ service efficiency [24]. However, the incentive mechanism no longer exists under the DIP payment system. Figure 1 provides the core design components of the DIP payment scheme.

Under the DIP payment scheme, the local government (LG) possesses significant autonomy while the central government establishes the basic policy framework. LG can set the regional global budget and devise policy details according to local conditions. Each DIP group is assigned a certain amount of point volume based on actual historical data to represent the relative resource utilization of different DIP groups [20]. Treating critical and severe cases consumes significantly more resources, resulting in a higher point volume, sometimes several

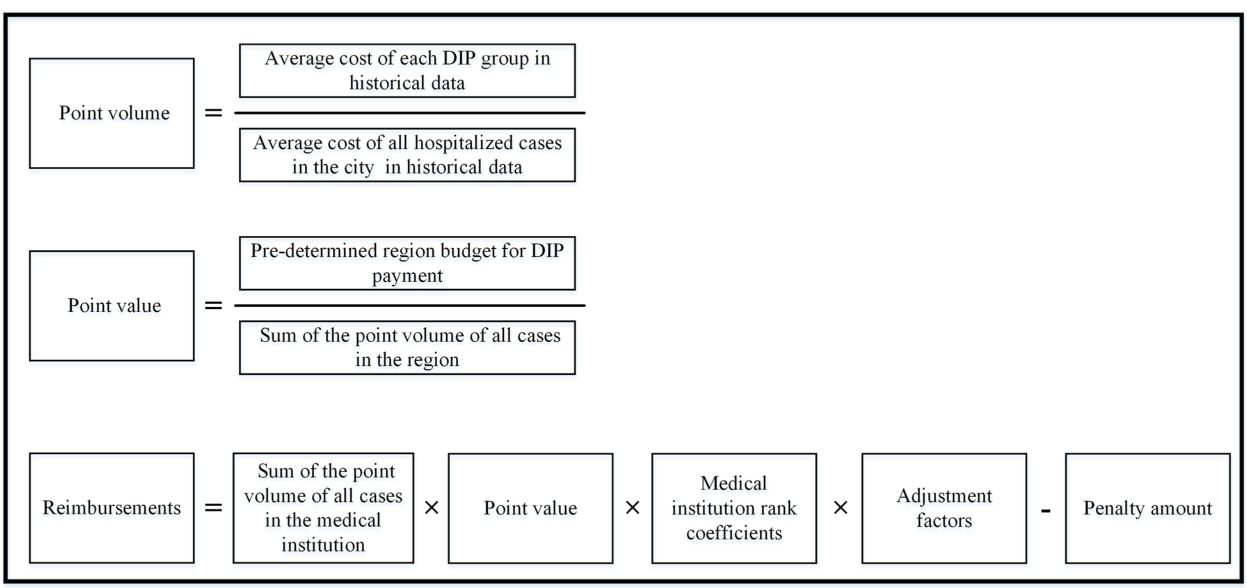

Fig. 1 Core components of the Diagnosis-Intervention Packet (DIP) payment scheme

times that of treating minor cases [21]. Consequently, medical institutions that handle critical and severe cases can receive more reimbursements from medical insurance management agencies, which generally means higher profits for SMI. The point value represents the actual value of each point, calculated by dividing the predetermined region budget for DIP payment by the sum of the point volume of all cases in the region. Notably, the Healthcare Security Administrations of DIP pilot cities have set up medical institution rank coefficients (MIRC), which reflect the proportion of resources consumed by different levels of medical institutions for treating cases within the same DIP group. The higher the medical institution level, the higher the MIRC. Medical institutions of the same level share the same MIRC. However, many DIP pilot cities have separately listed some common diseases, called primary DIP groups, and increased their MIRC for PMI. These diseases are easy to treat and have stable costs, making them suitable for PMI. Adjustment factors are determined based on the CCI index, age, and disease severity of the case. These factors are implemented to prevent potential cream skimming by medical providers, where they might select cases with the least ill and/or most financially rewarding [25]. Additionally, most DIP pilot cities have implemented a monitoring mechanism. Medical institutions face penalties for violating regulations such as upcoding or splitting hospitalizations. As shown in Fig. 1, the actual reimbursements to a medical institution are the product of the point volume, point value, MIRC, and adjustment factors minus the penalty. The Policymaker aims to design this economic incentive to encourage SMI to proactively refer minor cases to PMI for treatment, thereby reducing the burden on SMI.

During the DIP payment reform process, LG, SMI, and patients—acting as stakeholders—continuously compete and interact, with each participant striving to maximize their interests [26, 27]. LG represents the public interest and is responsible for the health protection of citizens. Its goal is to maximize the health benefits for citizens within budget constraints, ensure the stability and security of medical insurance funds, and improve the efficiency of funds utilization and health equity [28, 29]. SMI have a clear advantage in medical information and hold the authority to select cases and determine therapeutic regimes. Their value orientation in medical service activities is often dualistic. On the one hand, they aim to maximize social public interests by meeting patients' health needs and fulfilling their social responsibility of disease prevention and treatment. On the other hand, they seek to maximize their economic benefits, especially when financial subsidies are inadequate, which can lead to the waste of medical resources [30, 31]. Patients seek high-quality treatment at an affordable cost. Despite the frequent promotion of "patient-centered" care in official contexts, patients remain disadvantaged in the medical system. They are numerous and lack organization, preventing them from directly negotiating or bargaining with medical institutions. As a result, their interests are typically represented through the administrative actions of government agencies [32, 33]. Promoting the HMS requires the joint participation of LG, SMI, and patients. Therefore, building a mutually beneficial and win–win interest game mechanism for the three stakeholders should be the key to the success of medical reform. However, previous studies on medical systems have primarily focused on two-sided games, with the application of tripartite game models being relatively uncommon [34–36]. Moreover, according to Lucas Critique, any policy represents a game between policymakers and participants. As participants become familiar with the policy, their rational choices of optimal behavior will influence the long-term effectiveness of the policy [37]. The case-based payment scheme was a novel concept before implementing the DIP payment reform for LG, SMI, and patients in China. Therefore, the strategic choices of the participants in the game gradually evolved and stabilized toward an optimal strategy.

Based on this, we constructed a tripartite evolutionary game model to analyze the impact of implementing the DIP payment reform on the HMS in China. We verified the effectiveness of the model under various initial conditions through simulation analysis. Additionally, we analyze the stability of each participant's strategy and the sensitivity of parameters to ensure the analysis aligns closely with the situation in China. Finally, we provide valuable policy recommendations for the DIP payment reform.

Modeling

Assumptions and parameters

Hypothesis 1: The game involves three participants: LG, SMI, and patients. LG is participant 1, SMI are participant 2, and patients are participant 3. All three participants possess limited rationality, and their strategy choices evolve over time, eventually stabilizing at the optimal strategy.

Hypothesis 2: Each participant can adopt one of two strategies: supporting the HMS, denoted as supporters (S), or opposing it, denoted as opponents (O). The proportions of supporters among LG, SMI, and patients are x, y, and z $(x, y, z \in [0, 1])$, respectively. Consequently, the proportions of opponents are *1-x*, *1-y*, and *1-z*, respectively.

Hypothesis 3: When patients are supporters, they actively choose appropriate medical institutions based on their condition, promoting the HMS. If patients are opponents but SMI are supporters, SMI guide patients with minor illnesses to PMI, promoting the HMS. However, suppose both SMI and patients are opponents. In that case, many patients with minor illnesses crowd into these SMI, leading to wasted medical resources and hindering the promotion of the HMS.

Hypothesis 4: If the DIP payment reform promotes the HMS, it will benefit health equity and ensure the efficient and secure use of health insurance funds [38], bringing social benefits I to LG. Regions across China are increasingly engaging in dialogue and exchanges to share successful policy implementations, which is crucial for identifying effective strategies adaptable to local contexts [39]. In the early stages of the DIP payment reform, due to the general lack of experience and varying management capabilities across regions, the government sends officials to areas with better policy outcomes for learning purposes. LGs that implement effective policies provide experience for other regions [40]. Therefore, additional social benefits D can be created if LG, SMI, and patients are all supporters [41]. If the DIP payment reform does not promote the HMS, it will lead to a waste of medical resources and a loss of health insurance funds amounting to M. Under this premise, since LG has supervisory authority over medical institutions [42], it imposes a penalty H on SMI if LG is a supporter. Additionally, LG and SMI are regulated by the National Health Commission and the National Healthcare Security Administration [43]. If LG and SMI are opponents, the higher authorities penalize LG with a fine of P, $I > P > D$.

Hypothesis 5: If LG is a supporter, it supervises SMI at a regulatory cost of C_g, $P > C_g$. In addition to performing supervisory functions, LG will reward institutions that support its policies [44]. Thus, under this premise, if SMI are also supporters, LG awards SMI a bonus T. Furthermore, if patients are opponents, they resist government policies, causing a loss of reputation U for LG [45]. Suppose LG is an opponent, SMI are supporters, and patients are opponents. In that case, patients report SMI for refusing to admit them, resulting in LG imposing a penalty L on SMI [46].

Hypothesis 6: If the DIP payment reform promotes the HMS, the reimbursements and costs for SMI in treating patients are W_1 and S_1, respectively. If the DIP payment reform does not promote the HMS, the reimbursements and costs for SMI in treating patients are W_2 and S_2, respectively. Under the DIP payment scheme, the point volume for treating severe cases is significantly higher than for minor cases, so SMI can receive more profits, i.e., $W_1 - S_1 > W_2 - S_2$. However, because SMI guide patients with minor illnesses to PMI under the HMS, they will lose some patients [47], with the proportion of patient reduction being n ($n \in [0, 1]$).

Table 1 Payoff matrix of the game system involving the local government, superior medical institutions, and patients

Strategies			Payoffs		
LG	SMI	PA	LG	SMI	PA
S	S	S	$I - C_g - T + D$	$(W_1 - S_1)(1 - n) + T$	$Q_1 - C_1$
S	S	O	$I - C_g - T - U$	$(W_1 - S_1)(1 - n) + T$	$Q_3 - C_3$
S	O	S	$I - C_g$	$(W_1 - S_1)(1 - n)$	$Q_1 - C_1$
S	O	O	$-C_g - M + H$	$(W_2 - S_2) - H$	$Q_2 - C_2$
O	S	S	I	$(W_1 - S_1)(1 - n)$	$Q_1 - C_1$
O	S	O	$I + L$	$(W_1 - S_1)(1 - n) - L$	$Q_3 - C_3$
O	O	S	$I - P$	$(W_1 - S_1)(1 - n)$	$Q_1 - C_1$
O	O	O	$-M - P$	$W_2 - S_2$	$Q_2 - C_2$

Notes: *LG* the local government, *SMI* superior medical institutions, *PA* patients

Hypothesis 7: If patients are supporters and those with minor illnesses choose PMI for treatment, the perceived quality of the medical services they receive is Q_1, and the OOP payments are C_1. Suppose patients are opponents and SMI are also opponents. In that case, patients will prefer to go to SMI for treatment, where the perceived quality of the medical services they receive is Q_2, and the OOP payments are C_2. If patients are opponents but SMI are supporters, patients will initially go to SMI for treatment. However, SMI will direct patients with minor illnesses to PMI for treatment after examination and providing therapeutic regimes. In that case, the perceived quality of the medical services is Q_3, and the OOP payments are C_3. The OOP payments and perceived quality of the medical services are highest when patients visit SMI, lowest when they visit PMI, and moderate when patients are referred from SMI to PMI [48, 49]. Therefore, we assume that $Q_1 < Q_3 < Q_2$, $C_1 < C_3 < C_2$.

Based on these hypotheses, the payoff matrix for the game involving LG, SMI, and patients is constructed as shown in Table 1.

Analysis of evolutionarily stable strategies for replicator dynamic equations

The local government

The expected benefits for LG as a supporter (U_{1S}), as an opponent (U_{1O}), and the average expected benefits (U_1) are as follows:

$$\begin{cases} U_{1S} = (I - C_g - T + D)yz + (I - C_g - T - U)y(1 - z) + (I - C_g)(1 - y)z + (-C_g - M + H)(1 - y)(1 - z) \\ U_{1O} = (I)yz + (I + L)y(1 - z) + (I - P)(1 - y)z + (-P - M)(1 - y)(1 - z) \\ U_1 = xU_{1S} + (1 - x)U_{1O} \end{cases} \tag{1}$$

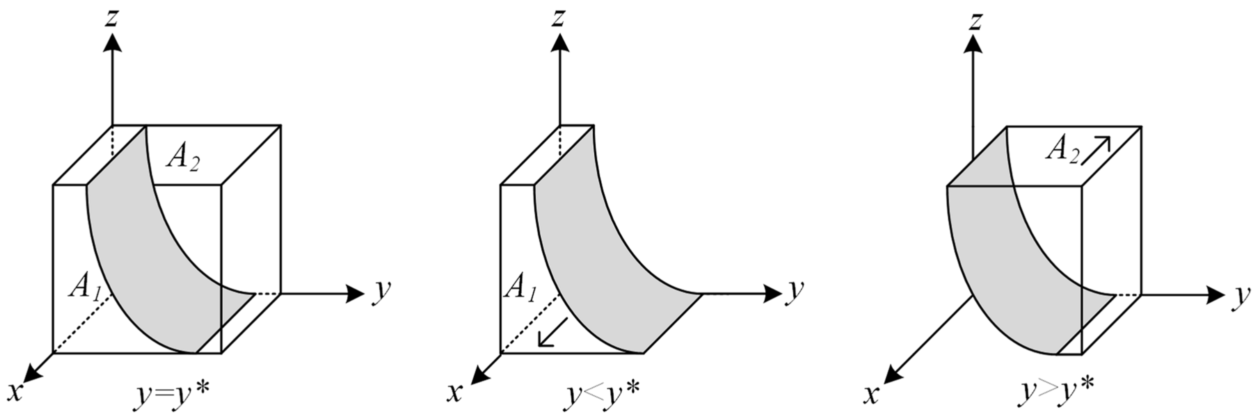

Fig. 2 Phase diagram of the local government's strategy evolution

Therefore, the replicator dynamic equation for LG is:

$$F(x) = \frac{dx}{dt} = x(U_{1S} - U_1) = x(x-1)\left[C_g - H - P + (H + L + P + T + U)y + Hz - (D + H + L + U)yz\right] \tag{2}$$

Taking the first-order derivative of *F(x)* yields:

$$\frac{d(F(x))}{dx} = (2x-1)\left\{C_g - H - P + y[H + L + P + T + U - (D + H + L + U)z] + Hz\right\} \tag{3}$$

According to the stability theorem of differential equations, the strategy chosen by LG must meet the following conditions to remain stable: $F(x)=0$ and $\frac{d(F(x))}{dx} < 0$. When $y = y* = \frac{-C_g+H+P-Hz}{H+L+P+T+U-(D+H+L+U)z}$, the system reaches a steady state, $x=1$ is the evolutionary stable strategy (ESS) of LG when $y<y^*$; $x=0$ is the ESS when $y>y^*$. The phase diagram of LG's strategy evolution is exhibited in Fig. 2. The probability of LG being a supporter is the volume of A_1, and the probability of being an opponent is the volume of A_2, calculated as:

$$V_{A1} = \int_0^1 \int_0^1 \frac{-C_g + H + P - Hz}{H + L + P + T + U - (D + H + L + U)z} dzdx$$
$$= \frac{H(D + H + L + U) + \left[-D(H + P) + HT - P(L + U) + C_g(D + H + L + U)\right]\left(\ln \frac{P+T-D}{H+L+P+T+U}\right)}{(D + H + L + U)^2}$$
$$V_{A2} = 1 - V_{A1}$$

.

Corollary 1: The probability of LG supporting the HMS decreases as the probability of SMI and patients supporting the HMS increases.

Corollary 2: The probability that LG supports the HMS is positively correlated with the additional social benefits created for other regions. It is negatively correlated with the penalties imposed on SMI when LG is an opponent and rewards to SMI, reputation losses, and supervision costs when LG is a supporter.

Superior medical institutions

The expected benefits for SMI as supporters (U_{2S}), as opponents (U_{2O}), and the average expected benefits (U_2) are as follows:

$$\begin{cases} U_{2S} = [(W_1 - S_1)(1 - n) + T]xz + [(W_1 - S_1)(1 - n) + T]x(1 - z) + [(W_1 - S_1)(1 - n)](1 - x)z + [(W_1 - S_1)(1 - n) - L](1 - x)(1 - z) \\ U_{2O} = [(W_1 - S_1)(1 - n)]xz + [(W_2 - S_2) - H]x(1 - z) + [(W_1 - S_1)(1 - n)](1 - x)z + [(W_2 - S_2)](1 - z) \\ U_2 = yU_{2S} + (1 - y)U_{2O} \end{cases} \tag{4}$$

Therefore, the replicator dynamic equation for SMI is:

$$F(y) = \frac{dy}{dt} = y(U_{2S} - U_2) = y(y-1)[L + (W_2 - S_2) - (W_1 - S_1)(1 - n) - (H + L + T)x - [L + (W_2 - S_2) - (W_1 - S_1)(1 - n)]z + (H + L)xz] \tag{5}$$

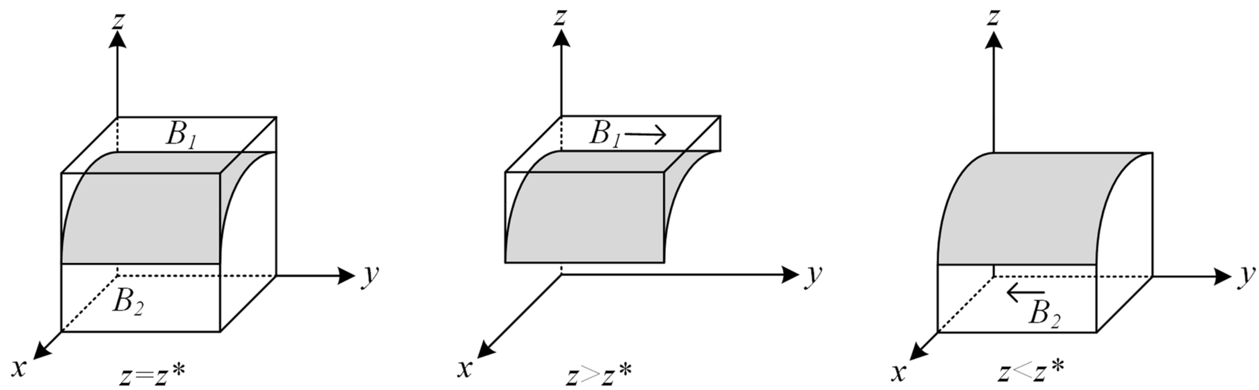

Fig. 3 Phase diagram of superior medical institutions' strategies evolution

Taking the first-order derivative of *F(y)* yields:

$$\frac{d(F(y))}{dy} = (2y-1)[L + (W_2 - S_2) - (W_1 - S_1)(1-n) - (H+L+T)x - [L + (W_2 - S_2) - (W_1 - S_1)(1-n)]z + (H+L)xz] \tag{6}$$

When $z = z* = \frac{L+(W_2-S_2)-(W_1-S_1)(1-n)-(H+L+T)x}{L+(W_2-S_2)-(W_1-S_1)(1-n)-(H+L)x}$, the system reaches a steady state, $y=1$ is the ESS of SMI when $z>z^*$; $y=0$ is the ESS when $z<z^*$. The phase diagram of SMI' strategies evolution is exhibited in Fig. 3. The probability of SMI being supporters is the volume of B_1, and the probability of being opponents is the volume of B_2, calculated as:

$$V_{B2} = \int_0^1 \int_0^1 \frac{(W_2 - S_2) - (W_1 - S_1)(1-n) + L - (H+L+T)x}{(W_2 - S_2) - (W_1 - S_1)(1-n) + L - (H+L)x} dxdy$$
$$= \frac{(H+L)(H+L+T) + T[L + (W_2 - S_2) - (W_1 - S_1)(1-n)] \ln \frac{H+(W_1-S_1)(1-n)-(W_2-S_2)}{-L+(W_1-S_1)(1-n)-(W_2-S_2)}}{(H+L)^2}$$
$$V_{B1} = 1 - V_{B2}$$

Corollary 3: The probability of SMI supporting the HMS increases as the probability of LG and patients supporting the HMS increases.

Corollary 4: The probability of SMI supporting the HMS is positively correlated with the rewards provided by LG when LG is a supporter.

Patients

The expected benefits for patients as supporters (U_{3S}), as opponents (U_{3O}), and the average expected benefits (U_3) are as follows:

$$\begin{cases} U_{3S} = (Q_1 - C_1)xy + (Q_1 - C_1)x(1-y) + (Q_1 - C_1)(1-x)y + (Q_1 - C_1)(1-x)(1-y) \\ U_{3O} = (Q_3 - C_3)xy + (Q_2 - C_2)x(1-y) + (Q_3 - C_3)(1-x)y + (Q_2 - C_2)(1-x)(1-y) \\ U_3 = zU_{3S} + (1-z)U_{3O} \end{cases} \tag{7}$$

Therefore, the replicator dynamic equation for patients is:

$$F(z) = \frac{dz}{dt} = z(U_{3S} - U_3) = z(z-1)[(Q_2 - C_2) - (Q_1 - C_1) + (Q_3 - C_3 - Q_2 + C_2)y] \tag{8}$$

Taking the first-order derivative of *F(z)* yields:

$$\frac{d(F(z))}{dz} = (2z-1)[(Q_2 - C_2) - (Q_1 - C_1) + (Q_3 - C_3 - Q_2 + C_2)y] \tag{9}$$

When $y = y** = \frac{(Q_1-C_1)-(Q_2-C_2)}{(Q_3-C_3)-(Q_2-C_2)}$, the system reaches a steady state. The ESS of patients is related to the value of Q_3-C_3-Q_2+C_2. When Q_3-C_3-Q_2+$C_2>0$, $z=1$ is the ESS of patients when $y<y^{**}$; $z=0$ is the ESS when $y>y^{**}$. When Q_3-C_3-Q_2+$C_2<0$, $z=0$ is the ESS of

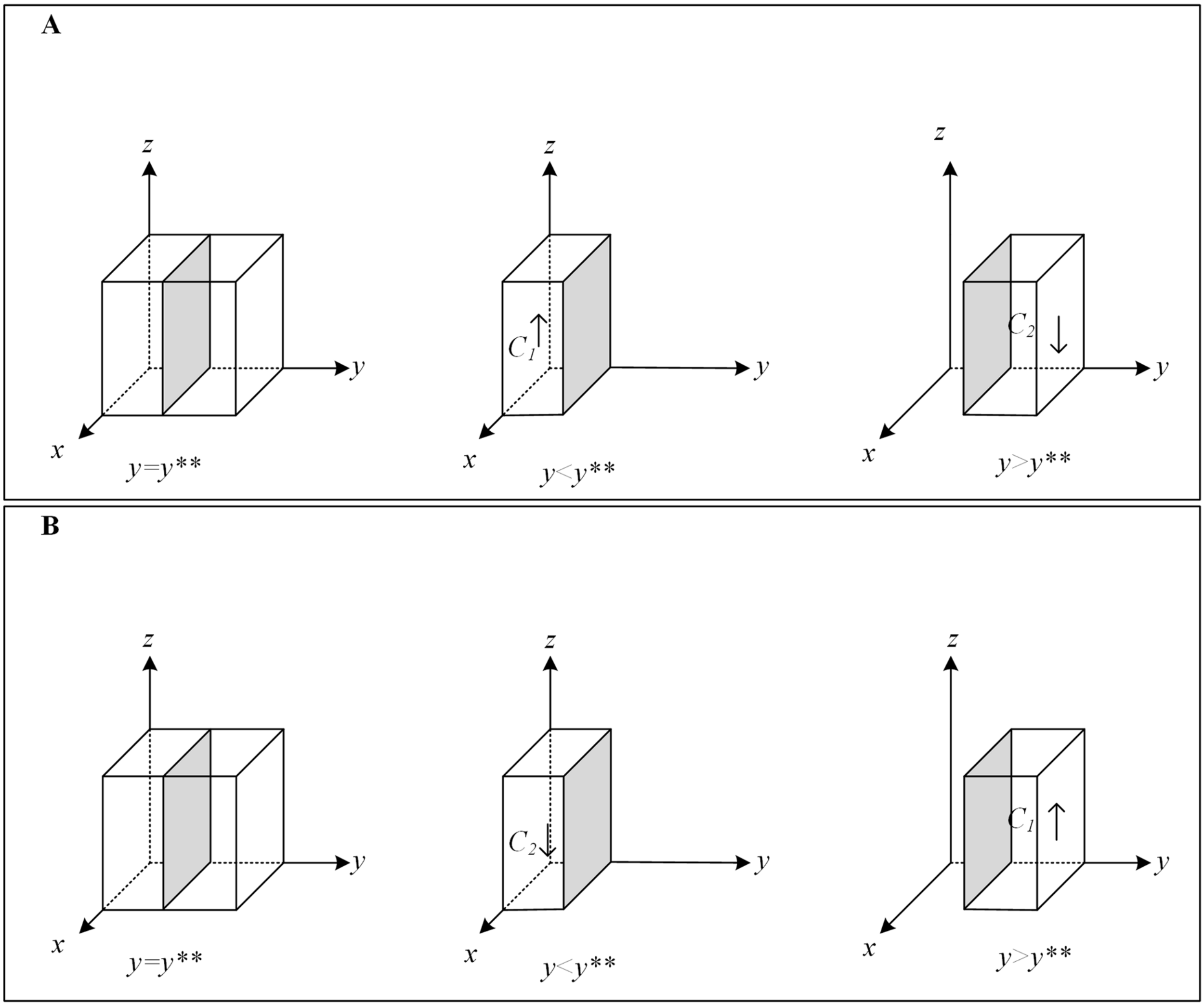

Fig. 4 Phase diagram of patients' strategies evolution. **A** Q_3-C_3-$Q_2+C_2>0$; **B** Q_3-C_3-$Q_2+C_2<0$

patients when $y<y^{**}$; $z=1$ is the ESS when $y>y^{**}$. The phase diagram of patients' strategies evolution is exhibited in Fig. 4. The probability of patients being supporters is the volume of C_1, and the probability of patients being opponents is the volume of C_2, calculated as:

$$(Q_3 - C_3) - (Q_2 - C_2) > 0:$$
$$V_{C1} = \int_0^1 \int_0^1 \frac{(Q_1 - C_1) - (Q_2 - C_2)}{(Q_3 - C_3) - (Q_2 - C_2)} dxdz = \frac{(Q_1 - C_1) - (Q_2 - C_2)}{(Q_3 - C_3) - (Q_2 - C_2)}$$
$$V_{C2} = 1 - V_{C1}$$
$$(Q_3 - C_3) - (Q_2 - C_2) < 0:$$
$$V_{C2} = \int_0^1 \int_0^1 \frac{(Q_1 - C_1) - (Q_2 - C_2)}{(Q_3 - C_3) - (Q_2 - C_2)} dxdz = \frac{(Q_1 - C_1) - (Q_2 - C_2)}{(Q_3 - C_3) - (Q_2 - C_2)}$$
$$V_{C1} = 1 - V_{C2}$$

Corollary 5: The probability of patients supporting the HMS is related to the probability of SMI supporting the HMS and is independent of the probability of LG supporting the HMS. When Q_3-C_3-$Q_2+C_2>0$, as the probability of SMI supporting the HMS increases, the

Table 2 Stability analysis of equilibrium points

E	Jacobian matrix eigenvalues				S	C
	λ_1	λ_2	λ_3	RPS		
$E_1(0,0,0)$	$Q_1-C_1-Q_2+C_2$	$H-C_g+P$	$(W_1-S_1)(1-n)-(W_2-S_2)-L$	(U,+, U)	N	/
$E_2(1,0,0)$	$Q_1-C_1-Q_2+C_2$	C_g-H-P	$H+T-(W_2-S_2)+(W_1-S_1)(1-n)$	(U, -, U)	ESS	a
$E_3(0,1,0)$	$Q_1-C_1-Q_3+C_3$	$L+(W_2-S_2)-(W_1-S_1)(1-n)$	$-C_g-L-T-U$	(U, U, -)	ESS	b
$E_4(0,0,1)$	0	$P-C_g$	$Q_2-C_2-Q_1+C_1$	(0,+, U)	N	/
$E_5(1,1,0)$	$Q_1-C_1-Q_3+C_3$	$(W_2-S_2)-T-H-(W_1-S_1)(1-n)$	$C_g+L+T+U$	(U, U,+)	N	/
$E_6(1,0,1)$	T	C_g-P	$Q_2-C_2-Q_1+C_1$	(+, -, U)	N	/
$E_7(0,1,1)$	0	$Q_3-C_3-Q_1+C_1$	$D-C_g-T$	(0, U, U)	N	/
$E_8(1,1,1)$	$Q_3-C_3-Q_1+C_1$	$-T$	$-D+C_g+T$	(U, -, U)	ESS	c

E Equilibrium Points, λ_1, λ_2, λ_3: the three eigenvalues of the Jacobian matrix, *RPS* real part sign, *S* stability, *ESS* Evolutionary stable strategy, *N* Non-stable, *C* Conditions for reaching equilibrium, condition a is $H+T-(W_2-S_2)+(W_1-S_1)(1-n)<0$, Q_1-C_1<Q_2-C_2, condition b is $L+(W_2-S_2)-(W_1-S_1)(1-n)<0$, Q_1-C_1<Q_3-C_3, condition c is $C_g+T<D$, Q_1-C_1>Q_3-C_3

probability of patients supporting the HMS decreases; when Q_3-C_3-Q_2+C_2<0, as the probability of SMI supporting the HMS increases, the probability of patients supporting the HMS increases.

Equilibrium and stability analysis

Let $F(x)=0$, $F(y)=0$, and $F(z)=0$, i.e., when the rate of change of the strategy choices is zero, we can obtain the eight pure strategy Nash equilibrium points of the evolutionary game system, namely $E_1(0,0,0)$, $E_2(1,0,0)$, $E_3(0,1,0)$, $E_4(0,0,1)$, $E_5(1,1,0)$, $E_6(1,0,1)$, $E_7(0,1,1)$, and $E_8(1,1,1)$. The Jacobian matrix of the system is as follows:

$$J=\begin{pmatrix} J_1 & J_2 & J_3 \\ J_4 & J_5 & J_6 \\ J_7 & J_8 & J_9 \end{pmatrix}=\begin{pmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{pmatrix}$$

$$=\begin{pmatrix} (2x-1)\left[C_g-H-P+(H+L+P+T+U)y+Hz-(D+H+L+U)yz\right] & x(x-1)[H+L+P+T+U-(D+H+L+U)z] & x(x-1)[H-(D+H+L+U)y] \\ y(y-1)[-H-L-T+(H+L)z] & (2y-1)[L+(W_2-S_2)-(W_1-S_1)(1-n)-(H+L+T)x-[L+(W_2-S_2)-(W_1-S_1)(1-n)]z+(H+L)xz] & y(y-1)[(W_1-S_1)(1-n)-(W_2-S_2)-L+(H+L)x \\ 0 & (z-1)(Q_3-C_3-Q_2+C_2) & (2z-1)[(Q_2-C_2)-(Q_1-C_1)+(Q_3-C_3-Q_2+C_2)y] \end{pmatrix}$$

Using the first method of Lyapunov, if all eigenvalues of the Jacobian matrix have negative real parts, the equilibrium point is asymptotically stable. The stability analysis of each equilibrium point is exhibited in Table 2.

Corollary 6: When $H+T-(W_2-S_2)+(W_1-S_1)(1-n)<0$, that is $n>1-\frac{W_2-S_2-H-T}{W_1-S_1}$, and Q_1-C_1<Q_2-C_2, the equilibrium point is $E_2(1,0,0)$. In that case, if SMI support the HMS, the proportion of patient reduction is high, and the economic benefits obtained are less than the benefits of being opponents. Due to the lower medical quality of PMI, patients are more inclined to oppose the HMS and directly seek treatment at SMI.

Corollary 7: When $L+(W_2-S_2)-(W_1-S_1)(1-n)<0$, that is $n<1-\frac{W_2-S_2+L}{W_1-S_1}$, and Q_1-C_1<Q_3-C_3, the equilibrium point is $E_3(0,1,0)$. In that case, if SMI support the HMS, the proportion of patient reduction is low, and the economic benefits obtained are more than the benefits of being opponents. Due to the lower medical quality of PMI, patients are more inclined to oppose the HMS. However, SMI will actively guide patients with minor illnesses to PMI for hospitalization. Therefore, the HMS can still be promoted. The financial burden on LG for supporting the HMS exceeds the cost of being an opponent. Additionally, since LGs as opponents do not incur penalties from higher authorities, they tend to withhold support for the HMS.

Corollary 8: When $C_g+T<D$, and Q_1-$C_1>Q_3$-C_3, the equilibrium point is $E_8(1,1,1)$. In that case, the additional social benefits created by LG for other regions are higher than the sum of the supervision cost and the rewards given to SMI, so LG tends to support the HMS. Due to the higher medical quality of PMI, patients are more inclined to support the HMS, allowing the HMS to be promoted. SMI tend to support the HMS to receive rewards from LG.

Simulation analysis of the evolutionarily stable strategy

To verify the effectiveness of the evolutionary stability analysis, we first collected medical data from six SMI and five PMI in two DIP pilot cities in Shandong Province in 2023. Both cities completed the DIP payment reform in January 2022. The LG strongly supports the development of the HMS in both cities, and the six SMI actively respond to this call by focusing primarily on treating severe cases. Therefore, we assume that all six SMI are under the HMS model. In 2023, the average revenue of these six SMI was USD 302.3 million, with approximately 50% (or USD 150 million) coming from reimbursements of medical insurance funds. For simplicity, we set the value of W_1 to 150. The average point volume at the six SMI was over 1600, while the primary DIP groups in both cities had an average point volume of only around 500 points. If the DIP reform does not promote the HMS, a large influx of patients in primary DIP groups will flow into these SMI. Based on the proportion of patients in primary DIP groups in the two cities, we estimate that reimbursements for these SMI would decrease by half in a non-HMS model. Thus, we set the value of W_2 to 80. Next, we determined the values of other economic parameters based on the ratios of various medical data to the average reimbursements of the six SMI. For example, the bonus provided by LG to each SMI is approximately one-thirtieth of their reimbursement, so the value of T was set to 5; the total OOP payments by SMI patients amounted to about one-fifth of their reimbursement, while PMI patients' OOP payments were about one-fifteenth of the SMI reimbursement. Therefore, the values of C_1 and C_2 were set to 10 and 30, respectively. For non-economic parameters, such as social benefits and perceived quality of the medical services, which are difficult to quantify, we referred to the values used in the studies by Tao et al. and Gong et al. [6, 50]. Then, we set different values for n to meet the conditions under various Corollaries. Based on this, we set the values of parameters to verify Corollary 6: $I=100$, $D=10$, $C_g=20$, $U=10$, $M=20$, $P=30$, $W_1=150$, $S_1=50$, $W_2=80$, $S_2=30$, $n=0.75$, $T=5$, $L=10$, $H=5$, $Q_1=50$, $C_1=10$, $Q_2=100$, $C_2=30$, $Q_3=80$, $C_3=20$, which meet the conditions stated in Corollary 6. Based on the previously given parameters, let $n=0.25$. This set of parameters meets the conditions of Corollary 7 and is used to verify Corollary 7. Finally, we changed the values of some parameters to meet the conditions of Corollary 8. Let $I=100$, $D=40$, $C_g=15$, $U=10$, $M=20$, $P=55$, $W_1=150$, $S_1=50$, $W_2=100$, $S_2=30$, $n=0.35$, $T=5$, $L=10$, $H=10$, $Q_1=55$, $C_1=5$, $Q_2=100$, $C_2=30$, $Q_3=75$, $C_3=30$, to verify Corollary 8. Simulations were conducted using MATLAB R2018a. The three sets of parameters have evolved 50 times from different initial strategies over time. The simulation results are shown in Fig. 5.

As exhibited in Fig. 5, under the conditions of Corollaries 6–8, the three sets of values underwent 50 iterations from various initial strategy combinations and ultimately converged at the equilibrium points $E_2(1,0,0)$, $E_3(0,1,0)$, and $E_8(1,1,1)$, respectively, indicating that the simulation results are consistent with the stability analysis.

Parameter sensitivity analysis

When the equilibrium point is $E_8(1,1,1)$, LG, SMI, and patients all support the HMS, which is most beneficial for the HMS and the rational allocation of medical resources.

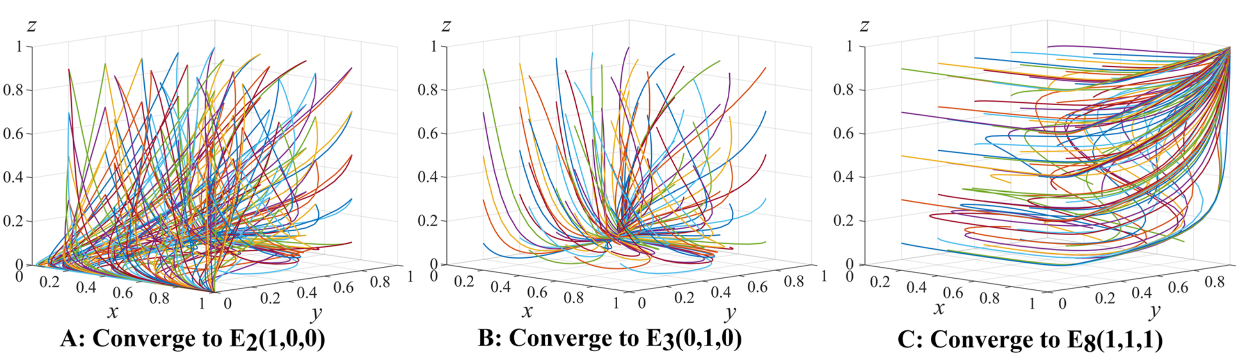

Fig. 5 Simulation Analysis of the evolutionarily stable strategy, **A** Converge to $E_2(1,0,0)$; **B** Converge to $E_3(0,1,0)$; **C** Converge to $E_8(1,1,1)$

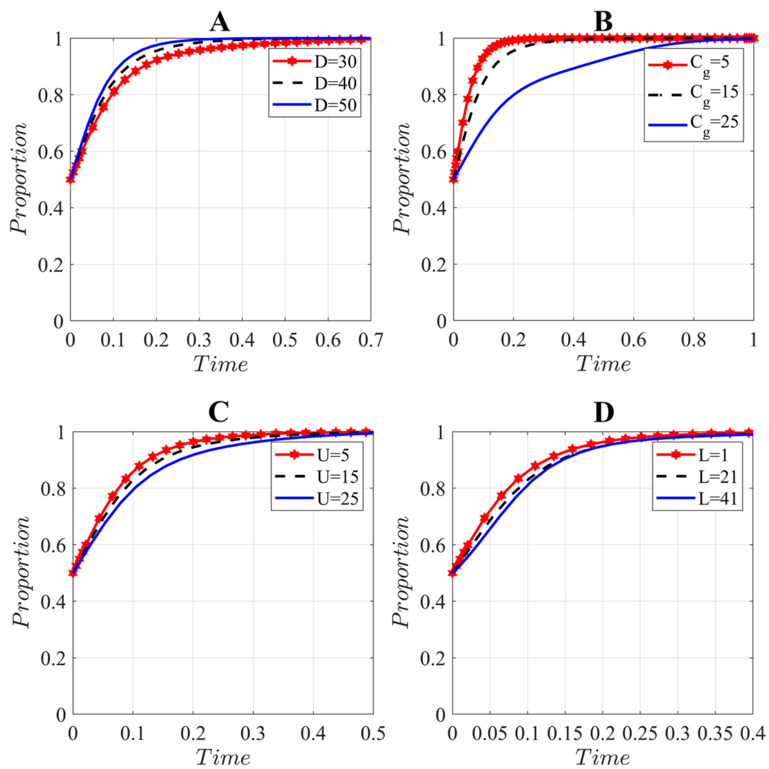

Fig. 6 The impact of parameters on the strategy of the local government. **A** The additional social benefits created for other regions; **B** Regulatory costs; **C** Reputation losses; **D** Fines imposed on superior medical institutions

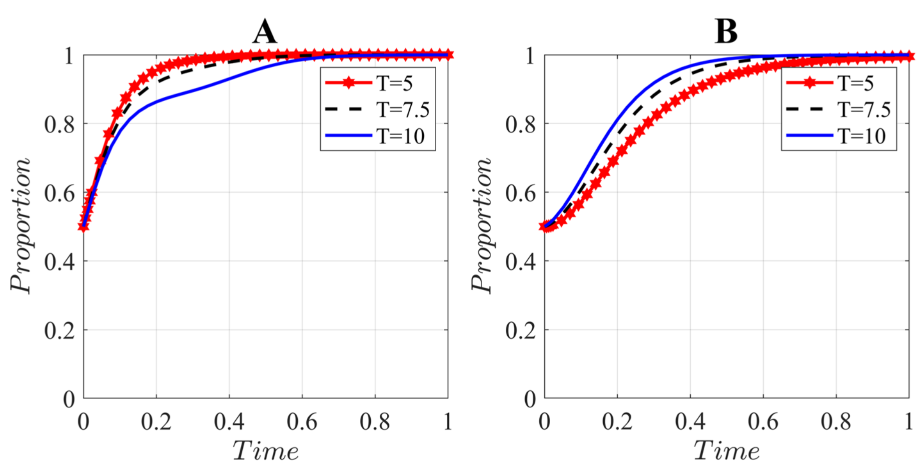

Fig. 7 The impact of the local government rewards to superior medical institutions on the strategies of both participants. **A** The impact of the local government rewards to superior medical institutions on the strategies of the local government; **B** The impact of the local government rewards to superior medical institutions on the strategies of superior medical institutions

Therefore, we applied parameters in line with Corollary 8 and assumed that the initial probability of each participant being a supporter is 0.5 to examine the impact of each parameter on the strategies of participants in the game. It is worth noting that when analyzing the effect of one of the parameters on the evolutionary game system, the values of other parameters are the same as the simulated values of the equilibrium point $E_8(1,1,1)$.

According to Corollary 2, the probability that LG supports the HMS is related to the additional social benefits created for other regions, regulatory costs, reputational loss, and fines imposed on SMI. We set $D = 30,40,50$,

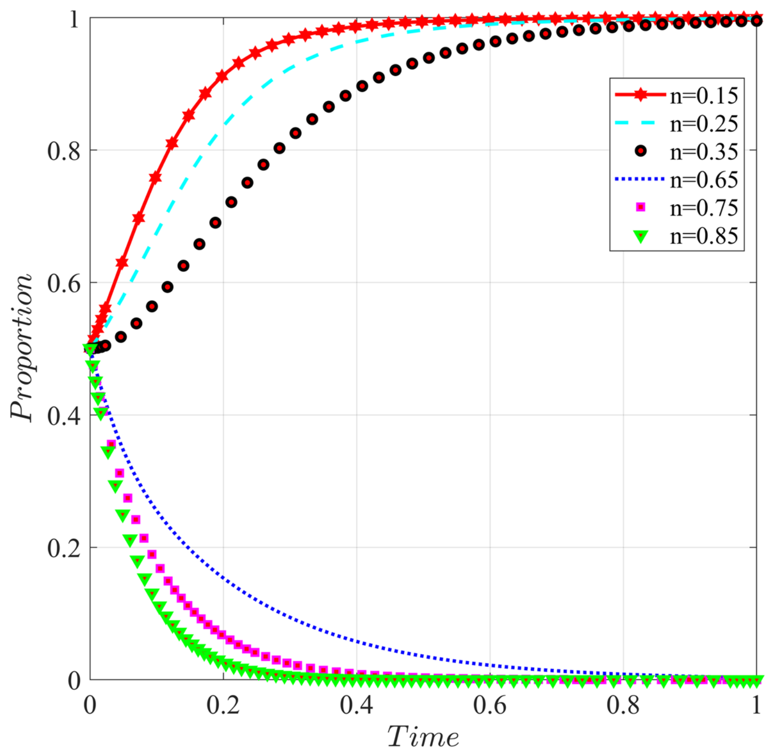

Fig. 8 The impact of the proportion of patient reduction under the DIP payment scheme on the strategies of superior medical institutions

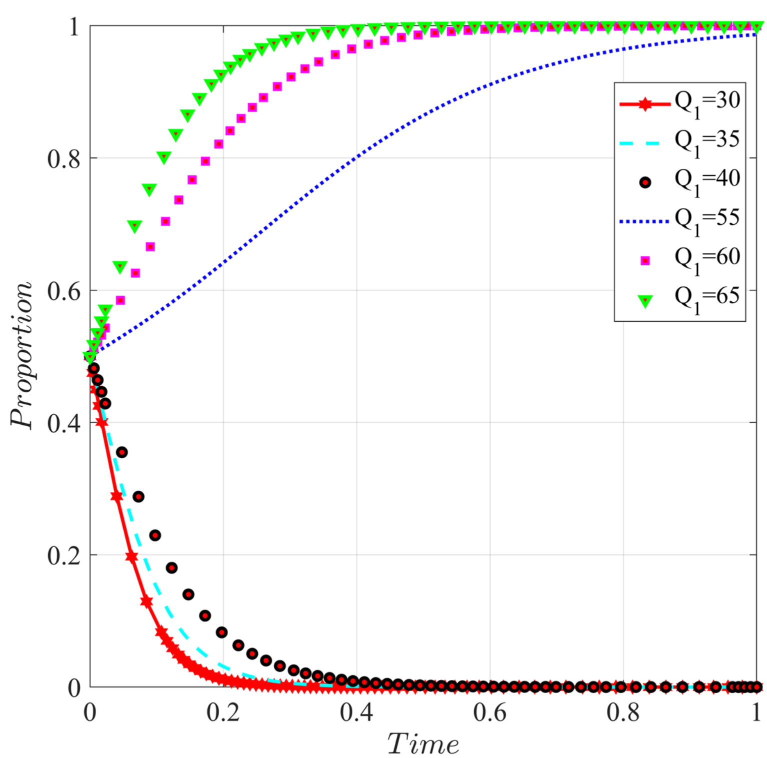

Fig. 9 The impact of perceived medical quality at primary medical institutions on the strategies of patients

$C_g = 5,15,25$, $U = 5,15,25$, and $L = 1,21,41$ to examine the impact of these parameters on the strategy of LG. As shown in Fig. 6A, as the additional social benefits created for other regions increase, the probability that LG supports the HMS increases, leading to a quicker evolution towards becoming a supporter. As shown in Fig. 6B, C and D, as the regulatory costs, reputation losses, and fines imposed on SMI increase, the probability that LG supports the HMS decreases, also slowing down the evolution of LG towards becoming a supporter. It can be inferred that LG aims to reduce costs while creating as many social benefits as possible and minimizing reputation losses.

According to Corollary 2 and Corollary 4, the rewards given by LG as a supporter to SMI that are also supporters impact the strategies of both participants. We set $T = 5$, 7.5, and 10 to verify the strategy evolution of LG and SMI. As shown in Fig. 7A and B, as the rewards from LG to SMI increase, the probability that LG acts as a supporter decreases, and the rate at which it evolves into a supporter slows down. Meanwhile, the probability that SMI act as supporters increases, and their rate of evolution into supporters accelerates. The increased reward is a greater incentive for SMI, while it means higher costs to support the HMS for LG.

According to Corollary 6 and Corollary 7, the strategies of SMI are related to the proportion of patient reduction. As shown in Fig. 8, the threshold for the proportion of patient reduction lies between 0.35 and 0.65. When n is below this threshold, the strategies of SMI evolve towards being supporters. The lower the n, the higher the probability that SMI choose to support the HMS, and the faster they evolve into supporters. When n is above this threshold, the strategies of SMI evolve into opponents. The higher the n, the higher the probability that SMI choose to oppose the HMS, and the faster they evolve into opponents, and the ESS of the system degenerates to $E_2(1,0,0)$. Thus, the proportion of patient reduction plays a decisive role in the strategies of SMI. When n is below the threshold, the total point volume of SMI as supporters under the DIP payment scheme is higher than opponents, allowing them to receive more reimbursements. However, when n increases above the threshold, due to the excessively high proportion of patient reduction, the total point volume of SMI as supporters decreases. Therefore, SMI tend to oppose the HMS.

As shown in Fig. 9, similar to the proportion of patient reduction, there is also a threshold for the perceived quality of the medical services patients receive in PMI, which lies between 40 and 55. When Q_1 is below this threshold, the strategies of patients evolve into opponents, and the ESS of the system degenerates to $E_3(0,1,0)$. The lower the Q_1, the higher the probability that patients oppose the HMS and the faster they evolve into opponents. When Q_1 is above this threshold, the strategies of patients evolve into supporters. The higher the Q_1, the higher the probability that patients support the HMS and the faster they evolve into supporters. Therefore, the perceived quality of the medical services patients receive in PMI plays a decisive role in their strategies. When the medical quality of PMI does not meet the patients' needs, patients are more likely to incur higher costs to visit SMI to obtain better-perceived medical quality.

Discussion

The game between LG, SMI, and patients as stakeholders is crucial to medical reform in China. Promoting the HMS requires the joint support of all three participants. However, during the DIP payment reform process, the participants have conflicting interests, each striving to serve their interests in the game. Therefore, only when specific conditions are met will all participants support the HMS.

Medical reform presents both significant challenges and opportunities for the government. It is a complex undertaking impacting public health, healthcare delivery, and citizen satisfaction. A well-structured institutional framework at the local level can positively influence the development of regional medical systems and offer valuable insights for policy design in other regions, especially for the Chinese government, which is in the early stages of case-based payment reform [51, 52]. For example, Jinhua City in Zhejiang Province redesigned the DRG payment scheme to improve policy deficiencies, and about 60 cities have learned from Jinhua's experience [19]. Similarly, the DIP payment scheme designed by Guangzhou City guided the policy design of the subsequent 71 pilot cities [21]. The Chinese government ensures each province has a DIP pilot city, paving the way for local adaptation and scaling up in the future [24]. However, at this stage, LGs are more focused on the impact of the DIP payment reform on outcomes such as expenditure and quality of care but lack specialized policy designs to promote the HMS. For LGs of pilot cities, improving the DIP policy to facilitate the implementation of HMS would inevitably provide valuable insights for policy design in other regions and create additional social benefits, which is an opportunity for LGs to enhance their credibility and gain the trust of higher-level authorities. Therefore, policymakers should encourage LGs that have successfully implemented advanced policies to share their experiences and insights with other regions.

The results of this study indicate that the proportion of patient reduction accepted by SMI under the DIP payment scheme is a determining factor affecting the strategies of SMI. It is worth noting that this reduction rate may vary significantly across different regions. China's medical resources are unevenly distributed, with significant disparities in medical standards across various regions. This imbalance challenges the country's healthcare system and affects patient access to high-quality care [53]. The distribution of high-quality medical resources in China is heavily concentrated in major urban areas, particularly in first-tier cities and provincial capitals such as Beijing, Shanghai, and Guangzhou. This concentration results in small cities and rural areas having limited access to advanced medical facilities and expertise [54]. Patients from these remote areas often travel across cities, especially those with severe illnesses, leading to a continuous influx of patients to top-tier medical institutions in major cities [55]. Even if SMI in major cities direct some minor cases to PMI, the proportion of patient reduction they accept will not be significant. In contrast, SMI in small cities face the risk of losing a substantial number of patients under the DIP payment scheme. Therefore, it can be inferred that under the DIP payment scheme, SMI in regions with developed medical resources are more supportive of the HMS. We also observed in Corollary 6 and Corollary 7 that the threshold for the proportion of patient reduction is related to LG's reward and punishment policies towards SMI. By appropriately increasing the rewards for SMI that support the HMS and the punishments for those that oppose it, the threshold for the proportion of patient reduction at which SMI shift from supporters to opponents can be raised, thereby increasing the probability of SMI supporting the HMS. Moreover, the expansion of large hospitals might be another hindrance to the HMS under the DIP payment scheme. Many large hospitals have continuously expanded their physical infrastructure in recent years to accommodate more patients and services. By 2021, China had 19 "super hospitals" with at least 4,000 beds [56]. Under the DIP payment scheme, empty beds mean that medical institutions cannot receive reimbursements; admitting patients with minor illnesses, although not yielding significant point volume, is still better than nothing. As beds increase, SMI may attract more medical demand from PMI, exacerbating the "siphon effect" [57]. Therefore, policy design should ensure public needs while controlling the excessive expansion of medical institutions.

The DIP payment reform focuses on resource allocation for medical institutions and does not alter the incentives for patients. Therefore, patients are primarily concerned with the quality of care and the OOP payments rather than the specific details of the DIP payment reform [58]. Although previous studies have shown that the quality of care and the OOP payments at various levels of medical institutions have changed under payment reforms, the results have been inconsistent. Additionally, we cannot determine the level of support LGs have for the HMS [20, 22, 59, 60]. Therefore, this paper does not consider the impact of LG's strategy on the quality of care and the OOP payments. Although gaining patient support for HMS in areas with poor medical quality of PMI is a significant challenge, this does not mean policymakers are powerless to promote HMS. By adjusting the MIRC, LG can alter the proportion of health insurance funds occupied by medical institutions of different levels. Theoretically, the DIP payment scheme can increase the income of PMI by appropriately raising their MIRC, enabling these institutions to attract high-quality professionals and improve medical facilities, thus enhancing medical quality. This process is not instantaneous and may take considerable time, requiring more practical evidence to prove its feasibility. However, it is undeniable that patients' support for the HMS depends on improving medical quality at PMI and increasing investment in primary healthcare.

This study has several limitations. First, medical systems are highly complex, and our model is merely an abstract simplification of the real-world system, which may not fully capture the changes experienced by participants in medical reform. Second, this study does not account for possible changes in point value during the implementation of DIP payment reform. In reality, as medical institutions tend to pursue higher point volume under the DIP payment scheme, the point value may decrease to some extent within a fixed expenditure budget, affecting the income of medical institutions. Although the results need to be confirmed in practice over a long period, this study provides a feasible methodology for analyzing the impact of payment reforms that can be used in future research.

Conclusion

In conclusion, the DIP payment scheme is more likely to promote the HMS in regions with an advanced policy framework, abundant medical resources, and high-quality primary medical services. The DIP payment scheme may not promote the HMS for other regions and could even hinder its construction. Policymakers need to create appropriate incentive systems to increase the probability of support for the HMS among the participants in the game.

Abbreviations

HMS	Hierarchical medical system
DIP	Diagnosis-Intervention Package
LG	The local government
SMI	Superior medical institutions
PMI	Primary medical institutions
MIRC	Medical institution rank coefficients
OOP	Out-of-pocket
ESS	Evolutionary stable strategy

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H.S. designed the study, wrote, and revised the manuscript. Z.C. substantively revised the manuscript. Z.C. conducted the analysis. All authors reviewed the manuscript.

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Declarations

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References

1. Shao Y, Luo W. Supply-demand adjusted two-steps floating catchment area (SDA-2SFCA) model for measuring spatial access to health care. Soc Sci Med. 2022;296:114727.
2. Ma X, et al. Incorporating multiple travel modes into a floating catchment area framework to analyse patterns of accessibility to hierarchical healthcare facilities. J Transp Health. 2019;15:100675.
3. Hou YX, et al. Levels, trends, and determinants of effectiveness on the hierarchical medical system in China: Data envelopment analysis and bootstrapping truncated regression analysis. Front Public Health. 2022;10:921303.
4. Wu QD, et al. Implementation efficiency of the hierarchical diagnosis and treatment system in China: a case study of primary medical and health institutions in Fujian province. Int J Health Plan Manage. 2022;37(1):214–27.
5. Liu N, et al. Unpacking the red packets: institution and informal payments in healthcare in China. Eur J Health Econ. 2021;22(8):1183–94.
6. Gong HX, et al. How can China's new health care reform promote the balance of interest game?-based on game evolution and simulation analysis. Risk Manage Healthcare Policy. 2023;16:1435–54.
7. Nundoochan A. Improving equity in the distribution and financing of health services in Mauritius, a small island state with deeply rooted welfare state standards. BMJ Glob Health. 2021;6(12):e006757.
8. Sun XY, et al. Can comprehensive medical reform improve the efficiency of medical resource allocation? Evidence from China. Int J Public Health. 2023;68:1606602.
9. Sun ZS, et al. Does descending health resources reform impact patient low-level hospital selection behavior? Evidence from Zhejiang, China. Arch Publ Health. 2021;79(1):179.
10. Han X, et al. How online ratings and trust influence health consumers' physician selection intentions: An experimental study. Telematics Inform. 2021;62:101631.
11. Hu XJ, et al. Healthcare needs, experiences and treatment burden in primary care patients with multimorbidity: an evaluation of process of care from patients' perspectives. Health Expect. 2022;25(1):203–13.
12. Ding Y, et al. The impacts of diagnosis-intervention packet payment on the providers' behavior of inpatient care-evidence from a national pilot city in China. Front Public Health. 2023;11:1069131.
13. Hu HX, et al. Medical insurance payment schemes and patient medical expenses: a cross-sectional study of lung cancer patients in urban China. BMC Health Serv Res. 2023;23(1):89.
14. Zhang Q, Li XD. Application of DRGs in hospital medical record management and its impact on service quality. Int J Qual Health Care. 2022;34(4):1–5.
15. Wu YS, et al. Evaluation of length of stay, care volume, in-hospital mortality, and emergency readmission rate associated with use of diagnosis-related groups for internal resource allocation in public hospitals in Hong Kong. JAMA Netw Open. 2022;5(2):e2145685.
16. Jian WY, et al. Beijing's diagnosis-related group payment reform pilot: Impact on quality of acute myocardial infarction care. Soc Sci Med. 2019;243:112590.
17. Wu J, et al. Can case-based payment contain healthcare costs? - A curious case from China. Soc Sci Med. 2022;312:115384.
18. Qian MC, et al. The pilot of a new patient classification-based payment system in China: The impact on costs, length of stay and quality. Soc Sci Med. 2021;289:114415.
19. Zhang T, et al. Impacts of a new episode-based payment scheme on volume, expenditures, and efficiency in public hospitals: a quasi-experimental interrupted time-series study in Jinhua, China. Risk Manage Healthc Policy. 2022;15:1659–69.
20. Chen YJ, et al. How do inpatients' costs, length of stay, and quality of care vary across age groups after a new case-based payment reform in China? An interrupted time series analysis. BMC Health Serv Res. 2023;23(1):160.
21. Lai Y, et al. Hospital response to a case-based payment scheme under regional global budget: The case of Guangzhou in China. Soc Sci Med. 2022;292:114601.
22. Lin K, et al. The impact of an innovative payment method on medical expenditure, efficiency, and quality for inpatients with different types of medical insurance: evidence from a pilot city, China. Int J Equit Health. 2024;23(1):115.
23. Annear PL, et al. Pathways to DRG-based hospital payment systems in Japan, Korea, and Thailand. Health Policy. 2018;122(7):707–13.
24. He AJ. Scaling-up through piloting: dual-track provider payment reforms in China's health system. Health Policy Plan. 2023;38(2):218–27.
25. Buczak-Stec E, et al. The impact of introducing a new hospital financing system (DRGs) in Poland on hospitalisations for atherosclerosis: An interrupted time series analysis (2004–2012). Health Policy. 2017;121(11):1186–93.
26. Ratigan K. Riding the tiger of performance legitimacy? Chinese villagers' satisfaction with state healthcare provision. Int Polit Sci Rev. 2022;43(2):259–78.
27. Liu Y, et al. China's health system performance. Lancet. 2008;372(9653):1914–23.
28. Wang L, et al. The development and reform of public health in China from 1949 to 2019. Glob Health. 2019;15:45.
29. Vilhjalmsson R. Public views on the role of government in funding and delivering health services. Scandinavian J Publ Health. 2016;44(5):446–54.
30. Xu J, et al. Reforming public hospital financing in China: progress and challenges. BMJ-Brit Med J. 2019;365:l4015.
31. Chen YP, et al. Disease concept-embedding based on the self-supervised method for medical information extraction from electronic health records and disease retrieval: algorithm development and validation study. J Med Internet Res. 2021;23(1):e25113.
32. Liu MC, et al. The influence of patient and hospital characteristics on inpatient satisfaction at Beijing District-Level Hospitals. Patient Prefer Adher. 2021;15:1451–60.
33. Ozoh OB, et al. Meeting unmet needs in chronic obstructive pulmonary disease diagnosis and treatment in low-and middle-income countries. Am J Respir Crit Care Med. 2023;208(4):352–4.
34. Mendonca FV, et al. Improving medical decision-making with a management science game theory approach to liver transplantation. Omega-Int J Manage Sci. 2020;94:102050.
35. Djulbegovic B, et al. Modern health care as a game theory problem. Eur J Clin Invest. 2015;45(1):1–12.
36. Li JL, et al. Study on the evolutionary strategy of upward patient transfer in the loose medical consortia. Math Biosci Eng. 2023;20(9):16846–65.
37. Lucas RE. Econometric policy evaluation: a critique. Carn-Roch Conf Ser Public Policy. 1976;1:19–46.

38. Wang Y, Chen H. The impact of the implementation of hierarchical medical system on population health: evidence from China. Front Public Health. 2024;12:1402832.
39. Nan R, Xiao YJ. How can policy diffusion of intergovernmental public health emergency cooperation be realized? Evidence from China. J Compar Policy Anal. 2024;26(5):466–86.
40. He AJ, et al. Seeking policy solutions in a complex system: experimentalist governance in China's healthcare reform. Policy Sci. 2022;55(4):755–76.
41. Barber SL, Yao L. Development and status of health insurance systems in China. Int J Health Plan Manage. 2011;26(4):339–56.
42. Shen YF, et al. Analysis of the characteristics, efficiency, and influencing factors of third-party mediation mechanisms for resolving medical disputes in public hospitals in China. BMC Publ Health. 2024;24(1):1823.
43. Dresser R, Frader J. Off-label prescribing: a call for heightened professional and government oversight. J Law Med Ethics. 2009;37(3):476.
44. Shi YQ, et al. Simulation of performance evaluation model for medical-elderly care integrated institutions based on system dynamics. BMC Health Serv Res. 2022;22(1):1451.
45. Song L, et al. Evolutionary game theory and simulations based on doctor and patient medical malpractice under government regulation. Sci Rep. 2023;13(1):18234.
46. Gao Y, et al. Has China's hierarchical medical system improved doctor-patient relationships? Heal Econ Rev. 2024;14(1):54.
47. Rao X, et al. A spatial feature analysis of primary health care utilization in a large city in China and its implications for family doctor contract service policy. BMC Health Serv Res. 2024;24(1):194.
48. Xu BB, et al. Financial toxicity and its risk factors among patients with cancer in China: a nationwide multisite study. Asia Pac J Oncol Nurs. 2024;11(5):100443.
49. Gao QF, et al. The impact of provider-patient communication skills on primary healthcare quality and patient satisfaction in rural China: insights from a standardized patient study. BMC Health Serv Res. 2024;24(1):579.
50. Tao CH, et al. How to promote the hierarchical diagnosis and treatment system: A tripartite evolutionary game theory perspective. Front Psychol. 2023;13:1081562.
51. Sun YL, et al. Chinese health care system and clinical epidemiology. Clin Epidemiol. 2017;9:167–78.
52. Williams C, Valentine N. Health in all policies at the local level: what facilitates success? Int J Health Policy Manage. 2023;12(1):7975.
53. Cai XZ, et al. Gap analysis on hospitalized health service utilization in floating population covered by different medical insurances ––- case study from Jiangsu Province, China. Int J Equit Health. 2019;18:84.
54. Yuan L, et al. Regional disparities and influencing factors of high quality medical resources distribution in China. Int J Equit Health. 2023;22(1):8.
55. Wang X, Nie X. The uneven distribution of medical resources for severe diseases in China: an analysis of the disparity in inter-city patient mobility. Appl Geogr. 2024;165:103226.
56. Xiao Y, et al. Patients gather in large hospitals: the current situation of Chinese hospitals and the direction of medical reform. Postgrad Med J. 2022;98(1166):e43.
57. Chen YQ, et al. COVID-19 as an opportunity to reveal the impact of large hospital expansion on the healthcare delivery system: evidence from Shanghai, China. Ann Transl Med. 2021;9(16):1297.
58. Jiang S, et al. Evaluating the effectiveness of public hospital reform from the perspective of efficiency and quality in Guangxi, CHina. Springerplus. 2016;5:1922.
59. Zeng JQ. The pilot results of 47 148 cases of BJ-DRGs-based payment in China. Int J Health Plan Manage. 2019;34(4):1386–98.
60. Tang X, et al. Variations in the impact of the new case-based payment reform on medical costs, length of stay, and quality across different hospitals in China: an interrupted time series analysis. BMC Health Serv Res. 2023;23(1):568.

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