Research on Performance Incentive Mechanism of General Practitioners under the Consideration of Reputation Effect

Ma zhi-qiang

Jiangsu University

Zhu Bin-xin (✉ zhubinxin44@163.com)

Jiangsu University <https://orcid.org/0000-0002-8810-7472>

Research

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1 **Research on Performance Incentive Mechanism of General**
2 **Practitioners under the Consideration of Reputation Effect**

3 Ma Zhi-qiang¹

4 Zhu Bin-xin^{1,2*}

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6 ¹School of Management, Jiangsu University, Zhenjiang, Jiangsu Province, China;

7 ²Centre for Competitive Creative Design, Cranfield University, Milton Keynes, Bedfordshire, UK

8

9 Correspondence: Zhu Bin-xin

10 No. 301, Xuefu Road, Jingkou District, Zhenjiang, Jiangsu Province, China, 212013

11 Tel: +86 18344813716

12 Email: zhubinxin44@163.com

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Abstract

Background: In China, General practitioners (GPs) have a weaker reputation than specialists, which leads to their low professional identity. Therefore, GPs' reputation is a bottleneck restricting their participation in skills training and the realization of the service value of community health centre. Because the GPs' reputation accumulation can only rely on the improvement of personal skills ,it is necessary to combine the improvement of medical skills to the future economic interests of the GPs, and establishing an effective dynamic reputation incentive mechanism. The purpose of this paper is to explore the dynamic reputation incentive mechanism for GPs, and analyze its performance.

Methods: In this paper, a dynamic incentive model of the GPs in two stages under the effect of explicit and implicit reputation is established and solved by using game theory and agent-principal theory.

Results: The explicit reputation affects GPs' determined incomes mainly through fixed awards, and the medical effort input in Stage 1 decreases with the performance award in Stage 2 under the reputation mechanism; the increase of the implicit reputation coefficient can improve the medical performance output, the performance award level and the total value of medical service value, and the explicit reputation correction factor plays the opposite role; when the implicit reputation coefficient and explicit reputation correct factor meet certain conditions, the implementation of reputation incentive can lead to the Pareto effect of GPs' medical effort and performance awards.

Conclusion: (1) explicit reputation mainly affects GPs' deterministic income in Stage 2 by changing the fixed benefits; (2) the medical efforts in the Stage 1 depend on the unit performance incentive coefficient in both stages, and show a certain ratchet effect; (3) implicit reputation can help to improve the level of medical efforts at each stage; (4) the reputation uncertainty will reduce the level of medical efforts and unit performance incentive at each stage; (5) when the explicit reputation correction coefficient is lower than a certain threshold, the implement of reputation incentive can realize the Pareto effect of medical efforts.

Keywords

medical service value; General Practitioners; reputation effect ; principal-agent theory; game theory

1. Background

General practitioners (GPs) are the essential part of community health services, and play an important role in preventive health care, common disease diagnosis and treatment, and patient rehabilitation management at the grassroots level [1]. Previous studies have shown that GPs' training skills can effectively increase the value of community health services. For example, it helps for more active participation in cancer screen, the management improvement of systemic diseases, and better solution to the epidemic public health crisis [2,3,4,5]. In China, because the reputation of community health care institutions nowadays is still far lower than the large general hospitals, the patient's trust in the level of community health service technology is relatively low, and the amount of medical visits is not high, which leads to the serious lack of willingness of GPs to invest in medical efforts [6]. According to statistics, the growth rate of primary health care in China from 2014 to 2015 is only 0.9%, which is far lower than 4.3% of general hospitals [7]. Unlike general hospital doctors, the GPs' reputation accumulation can only rely on the improvement of personal skills and cannot depend on the influence of organizations [8]. It can be seen that combining the improvement of medical skills to the future economic interests of the GPs, and establishing an effective dynamic reputation incentive mechanism are important ways to drive them to participate in skills training, and thus improve the quality of the medical services of community health institutions [9,10].

Most studies focus on service value of GPs, but there are little references to research the impact of reputation on medical performance of general practitioners which involves multi-stage objectives and dynamic decision-making [11,12,13,14,15]. Although Jiang and Li, Zhang & Zhu conducted qualitative studies [9,10], they failed to analyze the internal mechanism and specific operation of reputation incentive mechanism quantitatively. This paper combines the principal-agent theory to explore the dynamic reputation incentive mechanism for GPs on the basis of second-stage game, which provides inspiration for guiding GPs to improve medical efforts and realize the value of community health services.

2. Model Description and Assumption

We considers a two-stage principal-agent mechanism model between community health institutions and GPs. As the agent, GPs pay efforts to improve performance of medical services and gain certain benefits including fixed income and performance rewards from principal community health institutions.

Performance rewards is based on the GPs' medical service performance and adjusted according to the explicit reputation accumulated in the previous stage, which will undoubtedly affect GPs' economic benefit in the future. In addition, GPs also show a certain implicit reputation, that is, the medical costs will be shared at this stage due to the improvement of skills and reputation. The GPs' reputation incentive model is shown in Figure 1.

Figure 1 GPs two-stage dynamic reputation incentive mechanism model

GPs medical performance (measured by the quality of the medical services they provided) is determined by their medical efforts, reputation output, and certain random factors, which can be expressed as:

$$m_t = ke_t + \lambda r_t + \varepsilon_t, \quad t = 1, 2 \quad (1)$$

k is the medical efforts coefficient, which determines the extent to which medical efforts are translated into performance; e_t is the degree of medical effort of GPs in the stage t . λ is called the reputation output coefficient and r_t represents the explicit reputation (inferred as quality ability, qualification or public praise) of GPs in stage t . We assume that $r_t \sim N(a, \sigma_r^2)$ indicating that the GPs' expected reputation is a and exists uncertainty. ε_t represents random factors, and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$. We also assume ε_t and r_t are independent.

The information asymmetrical exists between the principal and the agent. That is, at each stage, community health institutions cannot observe the actual medical efforts put by GPs, and only reversely judge it according to the medical performance output. In Stage 1, community health organizations estimate the GP's medical effort to be e_1^* , and observe the actually medical performance m_1 , then revise GPs reputation output to λr_2 in Stage 2. According to the Shi et al, the revised GPs reputation output v is (Shi, Zhu & Sheng, 2017):

$$v = E(\lambda r_2 | m_1) = (1 - \tau)\lambda a + \tau(m_1 - ke_1^*) \quad (2)$$

That is to say, the revised reputation is a weighted average of the expected value λa and the actual observed value $m_1 - ke_1^*$. The correction coefficient τ ($0 < \tau < 1$) is the proportion of reputation output uncertainty in the total uncertainty of medical performance, namely

$$\tau = \frac{\lambda^2 \sigma_r^2}{\lambda^2 \sigma_r^2 + \sigma_\varepsilon^2} \quad (3)$$

τ indicates the explicit reputation stability. So we can get the variance of the reputation output:

$$\text{var}(v) = \tau^2 (\lambda^2 \sigma_r^2 + \sigma_\varepsilon^2) = \lambda^2 \tau \sigma_r^2 \quad (4)$$

In stage t , GPs receive a fixed income α_t and unit performance reward β_t . So the total income in stage t is expected to be:

$$w_t = \alpha_t + \beta_t (ke_t + \lambda r_t + \varepsilon_t) \quad (5)$$

We assume GPs have risk aversion whose utility function $U = -e^{-\rho \omega}$, where ρ is the degree of risk aversion, ω is the real monetary income. Medical cost (such as medical equipment loss, depreciation, energy loss) is a strictly monotonic incremental convex function for GPs' medical efforts, which can be expressed as:

$$C(e_t) = \frac{u}{2(1+\theta)} e_t^2 \quad (6)$$

Where $1+\theta$ is the implicit reputation coefficient of GPs, that is, due to good reputation, it will result in higher medical service value in the future which is reflected as the cost at present stage. Meanwhile, we

assume $\varphi = 1 + \theta > 1$. u is medical effort cost coefficient. So the total income of the principal community health institutions in stage t is:

$$U_t = (1 - \beta_t)m_t - \alpha_t = (1 - \beta_t)(ke_t + \lambda r_t + \varepsilon_t) - \alpha_t \quad (7)$$

3. Model construction and solution under the reputation incentive mechanism of GPs

3.1. Stage 2

According to the above description, the GP's expected revenue function in stage 2 is:

$$w_2 = \alpha_2 + \beta_2(ke_2 + \lambda r_2 + \varepsilon_2) - \frac{u}{2\varphi}e_2^2 \quad (8)$$

After the reputation is revised, the GP's deterministic revenue can be expressed as:

$$V_2 = \alpha_2 + \beta_2(ke_2 + v) - \frac{u}{2\varphi}e_2^2 - \frac{\rho\beta_2^2}{2}(\sigma_\varepsilon^2 + \lambda^2\tau\sigma_r^2) \quad (9)$$

Taking into account all the incentive costs, the deterministic net revenue of community health institutions is:

$$U_2 = (1 - \beta_2)(ke_2 + v) - \alpha_2 \quad (10)$$

Thus, the reputation incentive model of stage 2 can be expressed as followed:

$$\begin{aligned} \max_{\alpha_2, e_2, \beta_2} U_2 &= (1 - \beta_2)(ke_2 + v) - \alpha_2 \\ \text{s.t. (IR)} \quad &\alpha_2 + \beta_2(ke_2 + v) - \frac{u}{2\varphi}e_2^2 - \frac{\rho\beta_2^2}{2}(\sigma_\varepsilon^2 + \lambda^2\tau\sigma_r^2) \geq F_2 \\ \text{(IC)} \quad &e_2 \in \max \left[\alpha_2 + \beta_2(ke_2 + v) - \frac{u}{2\varphi}e_2^2 - \frac{\rho\beta_2^2}{2}(\sigma_\varepsilon^2 + \lambda^2\tau\sigma_r^2) \right] \end{aligned} \quad (11)$$

GPs decide the medical effort e_2 based on individual rationality constraint (IR) and incentive compatibility (IC). F_2 indicates the retain utility of GPs. According the constraint of IC, the equilibrium e_2^* is obtained by using the first-order partial derivative method. That is

$$e_2^* = \frac{k\varphi\beta_2}{u} \quad (12)$$

The principal community health institutions don't not allow GPs to earn benefits higher than F_2 under rational conditions. Therefore, we can take the equal sign in (IR) of Formula (11). According to Shi et al,

1 under the reputation mechanism, F_2 is the utility that may be generated by the best chance of giving up, i.e.
2 $F_2 = V_2 = \eta(U_2 + V_2)$, where η means the bargain power of GPs [15]. So, the deterministic revenue of
3 community health institutions about β_2 can be expressed as

$$4 \quad U_2 = (1-\eta) \left(\frac{\phi k^2 \beta_2}{u} + \nu - \frac{\phi k^2}{2u} \beta_2^2 - \frac{\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)}{2} \beta_2^2 \right) \quad (13)$$

5 Taking the first-order partial derivative of U_2 to β_2 , the optimal performance incentive coefficient is β_2^*
6 obtained. Then we put it in Formula (12) and get the equilibrium medical effort e_2^* :

$$7 \quad \beta_2^* = \frac{\phi k^2}{\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)}, e_2^* = \frac{\phi^2 k^3}{u(\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} \quad (14)$$

8 And the fixed income is:

$$9 \quad \alpha_2 = \frac{u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)}{\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)} \left(\frac{\phi^2 k^4}{u(\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu \right) - (1-\eta) \left(\frac{(1+\theta)^2 k^4}{2u(\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu \right) \quad (15)$$

10 Hence, the economic benefit of GPs and the community health institutions, and the total value of the
11 medical services (the sum of them two) in stage 2 are:

$$12 \quad U_2 = (1-\eta) \left(\frac{\phi^2 k^4}{2u(\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu \right), V_2 = \eta \left(\frac{\phi^2 k^4}{2u((1+\theta)k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu \right) \quad (16)$$

$$MV_2 = U_2 + V_2 = \frac{\phi^2 k^4}{2u(\phi k^2 + u \rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu$$

13 3.2. Stage 1

14 Let us go back to stage 1. Under the reputation mechanism, both parties would aim at maximizing the sum
15 of two stages deterministic revenues in Stage 1. Since Stage 1 is the initial phase, it is not possible to
16 correct GP's dominant reputation. Therefore, the decision goal of GPs is:

$$17 \quad V = \left(\alpha_1 + \beta_1(ke_1 + \lambda a) - \frac{u}{2\phi} e_1^2 - \frac{\rho \beta_1^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) + \left(\alpha_2 + \beta_2(ke_2 + \nu) - \frac{u}{2\phi} e_2^2 - \frac{\rho \beta_2^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) \quad (17)$$

18 The decision goal of community health institutions is:

$$19 \quad U = U_1 + U_2 = (1-\beta_1)(ke_1 + \lambda a) - \alpha_1 + (1-\beta_2)(ke_2 + \nu) - \alpha_2 \quad (18)$$

20 Thus, the reputation incentive model of Stage 1 can be expressed as followed:

$$\begin{aligned}
& \max_{\alpha_1, e_1, \beta_1} U = (1 - \beta_1)(ke_1 + \lambda a) - \alpha_1 + (1 - \beta_2)(ke_2 + \nu) - \alpha_2 \\
& s.t. \quad (IR) \left(\alpha_1 + \beta_1(ke_1 + \lambda a) - \frac{u}{2\varphi} e_1^2 - \frac{\rho\beta_1^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) + \left(\alpha_2 + \beta_2(ke_2 + \nu) - \frac{u}{2\varphi} e_2^2 - \frac{\rho\beta_2^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) \geq F \\
& (IC) e_{11} \in \max \left[\left(\alpha_1 + \beta_1(ke_1 + \lambda a) - \frac{u}{2\varphi} e_1^2 - \frac{\rho\beta_1^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) + \left(\alpha_2 + \beta_2(ke_2 + \nu) - \frac{u}{2\varphi} e_2^2 - \frac{\rho\beta_2^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) \right]
\end{aligned} \tag{19}$$

Here, F , the sum of the two-stage retention utility is an exogenous constant. Under the reputation mechanism, the performance of Stage 1 would change the reputation output ν of Stage 2, hence affect the level of medical efforts in Stage 2. Substituting $\nu = (1 - \tau)\lambda a + \tau(m_1 - ke_1^*)$ into (IC) condition of Formula (19), and taking the first-order partial derivative U_2 of to e_1 , we can get

$$e_1^* = \frac{\varphi k (\beta_1 - \tau \beta_2)}{u} \tag{20}$$

Similarly to stage 2, taking the equal sign in (IR), and substitute it and take into U , we get

$$U = \left(ke_1(\beta_1) + \lambda a - \frac{u}{2\varphi} e_1^2 - \frac{\rho\beta_1^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) + \left(ke_2 + (1 - \tau)\lambda a + \tau(m_1 - ke_1(\beta_1)) - \frac{u}{2\varphi} e_2^2 - \frac{\rho\beta_2^2}{2} (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) - F \tag{21}$$

The equilibrium performance incentive coefficient β_1^* and medical effort e_1^* are obtained by the first-order partial derivative method:

$$\begin{aligned}
\beta_1^* &= \frac{\varphi k^2 (1 - \tau + \tau \beta_2^*)}{\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2)} = \frac{\varphi k^2 (\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)(1 - \tau))}{(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2))(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))}, \\
e_1^* &= \frac{k\varphi(\varphi k^2 (1 - \tau) - u\rho\sigma_\varepsilon^2 \tau \beta_2^*)}{u(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2))} = \frac{\varphi^2 k^3 (\varphi k^2 (1 - \tau) + u\rho((1 - 2\tau)\sigma_\varepsilon^2 - \lambda^2 \tau^2 \sigma_r^2))}{u(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2))(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))}
\end{aligned} \tag{22}$$

The deterministic revenue of community health institutions and total value of medical services are:

$$\begin{aligned}
U_1^* &= \left(ke_1^* + \lambda a - \frac{u}{2\varphi} e_1^{*2} - \frac{\rho\beta_1^{*2}}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) + \eta \left(\frac{\varphi^2 k^4}{2u(\varphi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2))} + \nu \right) - F \\
MV_1^* &= U_1^* + V_1^* = (ke_1^* + \lambda a) - \frac{u}{2\varphi} e_1^{*2} - \frac{\rho\beta_1^{*2}}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) = \frac{(1 + \tau)\varphi k^2 (\beta_1^* - \tau \beta_2^*)}{2u} - \frac{\rho\tau \beta_1^* \beta_2^*}{2} (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2)
\end{aligned} \tag{23}$$

4. Incentive mechanism without consideration of reputation

In this case, GPs' medical performance has nothing to do with reputational factors such as qualifications and public praise. Therefore, the incentive mechanism of Stage 1 is consistent with that of Stage 2. The medical performance can be expressed as:

$$m = ke + \xi \quad (24)$$

Where ξ is the uncertainty of medical performance caused by factors such as medical policy and medical technology advancement, and we can assume that $\xi \sim N(0, \lambda^2 \sigma_r^2 + \sigma_\varepsilon^2)$. Without considering the implicit reputation, the medical effort cost will be changed into $\frac{u}{2}e^2$ and the parameters of fixed income and unit performance reward are unchanged. Therefore, the economic benefit is

$V = \alpha + \beta ke - \frac{u}{2}e^2 - \frac{\rho\beta^2}{2}(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2)$. The incentive model is expressed as follows:

$$\begin{aligned} \max_{\alpha_2, e_{12}, \beta_{12}} \quad & U = (1 - \beta)ke - \alpha \\ \text{s.t.} \quad & (\text{IR}) \alpha + \beta ke - \frac{u}{2}e^2 - \frac{\rho\beta^2}{2}(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \geq F_0 \\ & (\text{IC}) e \in \max \left[\alpha + \beta ke - \frac{u}{2}e^2 - \frac{\rho\beta^2}{2}(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right] \end{aligned} \quad (25)$$

The expressions for equilibrium medical effort and performance incentive coefficient are:

$$\beta^* = \frac{k^2}{k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2)}, e^* = \frac{k^3}{u(k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2))} \quad (26)$$

5. Results

5.1 Sensitivity analysis results

Conclusion 1: (1) β_2^* and ν are irrelevant; (2) when $\eta > \beta_2^* = \frac{\phi k^2}{\phi k^2 + u\rho(\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2)}$, reputation output

has a positive effect on fixed income α_2 ; when $\eta < \beta_2^*$, reputation output has a negative effect on α_2 .

Conclusion 1 indicates that the GPs' explicit reputation mechanism affects the future economic benefit by adjusting their fixed income. In other words, in Stage 2, community health institutions should change the GPs' fixed income based on the reputation m_1 gained from the observed previous medical performance.

When the bargain ability is high ($\eta > \beta_2^*$), due to the higher medical efforts in stage 1, the explicit

reputation output has a positive effect on fixed benefits. Vice versa. Therefore, from the perspective of reputation revenue, GPs should actively improve professional skills to enhance the initial stage's medical performance and their bargaining power, so as to obtain higher fixed income in the future.

Conclusion 2: (1) e_1^* is positively related to β_1^* , negatively related to β_2^* ; (2) e_2^* is only positively related with β_2^* , while has no relationship with β_1^* .

This conclusion indicates that, in final stage (Stage 2) the reputation mechanism does not work. Therefore, the medical efforts are only related to the performance incentive coefficient. However, medical efforts of Stage 1 is related to two stages' performance incentive coefficient, and will decrease as the performance incentive coefficient of Stage 2 increases. That is, reputation will have a certain ratchet effect. We can learn

from $\frac{\partial e_1^*}{\partial \beta_2} = \frac{-\phi k \tau}{u}$ that, the ratchet effect is positively correlated with the medical effort output coefficient k ,

and the reputation correction coefficient τ , negatively correlated with effort cost coefficient u . Therefore, it is unfavorable of too much use of reputation to modify GPs' performance outcomes.

Conclusion 3: (1) e_2^* is positively related to ϕ , β_2^* is positively related to ϕ ; (2) e_1^* is positively related to ϕ , β_1^* is positively related to ϕ .

This conclusion suggests that the effect of implicit reputation has a continuously positive effect on GPs' efforts. No matter at which stage, the higher the implicit reputation, the greater the level of unit performance rewards given by the community health organization, so the higher input level of GPs medical efforts. Therefore, continuous participation in cost-reducing training, improvement of medical proficiency, provision of efficient services for patients and continuous improvement of implicit reputation are conducive to enhancing the effect of reputation incentive.

Conclusion 4: (1) e_1^* is negatively related to τ , β_1^* is negatively related to τ ; (2) e_2^* is negatively related to τ , β_2^* is negatively related to τ .

This conclusion shows that the reputation correction coefficient always plays a negative role in the effect of reputation incentives. In Stage 1, the higher the reputation correction coefficient, the more uncertain the patients are about the GP's ability, the cumulative reputation has a more pronounced impact on future

medical performance, the ratchet effect is enhanced, and the GP's medical efforts are reduced. In Stage 2, although there is no need to consider future revenues, the improvement of the reputation correction coefficient will increase the uncertainty of the medical performance output at this stage and they will avoid revenue risk by reducing medical efforts.

Conclusion 5: (1) MV_2 is positively related to ν , negatively related to τ , and positively related to φ ; (2) MV_1 is negatively related to τ , positively related to φ , and uncorrelated with ν .

We can see that, the higher the revised GP's reputation performance output ν , the better the value of future medical services; meanwhile, the current service value will not be affected. In addition, the uncertainty of explicit reputation τ will reduce the total service value too, which means GPs should also strive to maintain the stability of their reputation. Finally, the total value of medical services will increase as the implicit reputation coefficient φ increases. Therefore, cost-reduction training must be introduced to GP, which will help to enhance GP's implicit reputation and contribute to the realization of the total value of community health institutions.

5.2. Comparative analysis and simulation results

Conclusion 6: $e^* < e_2^*$, $\beta^* < \beta_2^*$.

The conclusion shows that GPs' medical efforts and performance incentive coefficient in stage 2 are improved under the reputation incentive mechanism. On the one hand, as the effect of implicit reputation is continuous, the effort cost is higher than that under the non-reputation mechanism; on the other hand, the variance of the medical performance output revised by the explicit reputation is $\lambda^2\tau\sigma_r^2 + \sigma_e^2$, lower than $\lambda^2\sigma_r^2 + \sigma_e^2$ when there is no reputation incentive. That is, the medical performance uncertainty in Stage 2 will be reduced, which will drive GPs to pay higher efforts and obtain greater medical performance.

Conclusion 7: (1) when $\varphi k^2 \left((\varphi - 1) (\sigma_e^2 + \lambda^2 \sigma_r^2) - \tau (\sigma_e^2 + \lambda^2 \tau \sigma_r^2) \right) > (\varphi \tau + 1 - \varphi) u \rho (\sigma_e^2 + \lambda^2 \sigma_r^2) (\sigma_e^2 + \lambda^2 \tau \sigma_r^2)$ is satisfied, we have $\beta^* < \beta_1^*$; otherwise, $\beta^* > \beta_1^*$; (2) when

1 $\varphi^2 \left(\phi k^2 (1-\tau) + u \rho \left((1-\tau) \sigma_\varepsilon^2 - \tau (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right) \right) \left(k^2 + u \rho (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) > \left(\phi k^2 + u \rho (\sigma_\varepsilon^2 + \lambda^2 \sigma_r^2) \right) \left(\phi k^2 + u \rho (\sigma_\varepsilon^2 + \lambda^2 \tau \sigma_r^2) \right)$ is satisfied, we

2 have $e^* < e_1^*$; otherwise, $e^* > e_1^*$.

3 The conclusion shows that only when the explicit reputation correction coefficient τ and the implicit

4 reputation coefficient φ satisfy certain conditions, the reputation incentive mechanism will be beneficial to

5 simultaneously improve GPs' medical efforts and performance incentive coefficient in Stage 1. For the

6 complex relationship between medical efforts coefficient and performance incentive coefficient, the

7 simulation is carried out below. Let us set medical effort conversion coefficient $k = 70$, explicit reputation

8 output coefficient $\lambda = 1$, random variance $\sigma_\varepsilon^2 = 80$, medical effort cost coefficient $u = 50$, GPs' risk

9 aversion coefficient $\rho = 2$. Boundary curves of $\beta_1^* = \beta^*$ and $e_1^* = e^*$ with respect to τ and φ are

10 respectively made, then region maps of $\beta_1^* > \beta^*$, $e_1^* > e^*$ are obtained (Figure 2 and Figure 3).

Figure 2 The effect of φ, τ on relationship

of β_1^* and β^*

Figure 3 the effect of φ, τ on relationship

of e_1^* and e^* .

14 We can see clearly that the area at the upper left of the curve in Figure 2 satisfies $\beta_1^* > \beta^*$, that is, within

15 the parameter range of the region, the unit performance incentive coefficient of both stage is higher than

16 under the non-reputation mechanism, and the reputation incentive achieves the Pareto effect of performance

17 encouragement. This case can appear if the implicit reputation coefficient φ is higher or the explicit

18 reputation correction coefficient τ is lower than a certain threshold. In addition, it can also be seen that the

19 larger the k , the lower the position of the boundary curve, explaining that the greater performance

conversion of medical efforts causes the higher probability of Pareto effect of performance encouragement, and the greater possibility that GPs will receive performance benefit from reputation incentives.

Figure 3 shows that the slope of the boundary curve of $e_1^* = e^*$ is very large, almost perpendicular to the horizontal axis and the left region of it simultaneously satisfy $e_1^* > e^*$ and $e_2^* > e^*$. That is, the reputation incentive can lead to the Pareto effect of medical efforts. We can see that τ has a significant impact on GP's medical efforts. When τ is lower than a threshold, a nearly small φ can achieve the Pareto effect; while greater than this threshold, even if φ is high, it is difficult to achieve. In addition, the larger the k , the more the boundary curve shifts to the left, and the smaller the region of $e_1^* > e^*$. This shows that the performance conversion of medical efforts has less influence on GPs' medical efforts than the non-reputation incentive. The more easily medical efforts are translated into performance, the more the community health organizations need to rely on stable reputation output to motivate GPs.

6. Conclusions and Implications

6.1 Conclusions

The medical performance of GPs plays an important role in realizing the service value of community health system. GPs with good reputation have obviously advantages in attracting patients and reducing medical risks. In this paper, principal-agent model is used to study the GPs' reputation incentive mechanism. Considering that community health institutions adjust the explicit reputation according to the performance of GPs in Stage 1, the expected medical performance in Stage 2 is changed. We define implicit reputation as the sharing of effort cost due to the improvement of skills and reputation.

The main conclusions of this study are as follows: (1) explicit reputation mainly affects GPs' deterministic income in Stage 2 by changing the fixed benefits; (2) the medical efforts in the Stage 1 depend on the unit performance incentive coefficient in both stages, and show a certain ratchet effect; (3) implicit reputation can help to improve the level of medical efforts at each stage, which will improve the economic benefits of community health institutions and the whole

1 medical service value of health system; (4) the reputation uncertainty will reduce the level of
2 medical efforts and unit performance incentive at each stage, and is not conducive to the service
3 value of medical system; (5) when the explicit reputation correction coefficient is lower than a
4 certain threshold, the implement of reputation incentive can realize the Pareto effect of medical
5 efforts in each stage, and the performance conversion rate of medical effort can help to reduce the
6 threshold.

7 **6.2 Implications**

8 The conclusions provide useful implications to improve the GPs' medical performance in
9 community health constitutions. It is necessary for community health constitutions to establish a
10 long-term reputation incentive mechanism and improve the dynamic reputation evaluation system
11 for GPs. In view of the complexity of GPs' reputation evaluation, it is necessary to refine the
12 evaluation indicators and consider such factors as the outpatient workload, the number and
13 composition of residents, the quality of service and patient satisfaction, so as to effectively reflect
14 GPs' comprehensive ability formed in the process of long-term dynamic medical service.
15 Furthermore, reputation evaluation cannot be done once for all, but the reputation score should be
16 constantly adjusted according to the pre-performance of GPs, as the basis for the post-
17 performance reward. They can also make full use of the current network and other media means
18 to attract more people to participate in reputation evaluation, and establish a social evaluation and
19 supervision mechanism of professional reputation.

20 The standardized GPs' skills training system should be established so as to effectively improve
21 their medical quality and skill level. In view of the different roles of explicit reputation and
22 implicit reputation, the categories of medical training should be classified as skill-enhancing,
23 quality-improving and cost-reducing. In this way, we can increase the service quality and
24 marginal medical performance. Meanwhile, improving the proficiency of GPs' daily medical
25 service process in order to reduce the cost of the medical effort and increase the implicit
26 reputation coefficient. What's more, GPs should establish the idea of lifelong learning and

1 training, divide their career into different stages, and set different training contents and
2 curriculum plans respectively.

3 Community health institutions must devote themselves to improving the internal management
4 mechanism and strengthening patients' trust in GPs, which will reduce the negative impact of
5 explicit reputation uncertainty coefficient . Firstly, perfect community medical information
6 disclosure system is very important to reduce information asymmetry between GPs and patients.
7 That is, community health institutions should regularly publish detailed information on medical
8 services, medicines and GPs' qualifications and abilities. This is not only conducive to balance
9 the distribution of medical information between the supply and demand side, but also indirectly
10 form an urge mechanism for GPs to keep learning and reduce the uncertainty of GPs' reputation.
11 Secondly, community health institutions should not only focus on the personal reputation of GPs,
12 but also on the expansion of the reputation of the whole community health care system from
13 internal management mechanism of themselves.

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1 List of abbreviations

Abbreviations	Description
m_t	GPs' medical performance of stage t
e_t	GPs' medical effort of in the stage t
r_t	GPs' explicit reputation of stage t , and $r_t \sim N(a, \sigma_r^2)$
σ_r	Standard deviation of r_t
ε_t	Random factors of medical performance of stage t , and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$
σ_ε	Standard deviation of ε_t
k	Medical efforts coefficient, which determines the extent medical efforts are translated into performance
λ	The reputation output coefficient, which determines the extent explicit reputation are translated into performance
ν	The revised GPs reputation output
τ	The correction coefficient . that is , the proportion of reputation output uncertainty in the total uncertainty of medical performance
α_t	GPs' fixed income of stage t
β_t	GPs' unit performance reward of stage t
w_t	GPs' total benefit of stage t
ρ	Degree of GPs' risk aversion
$C(e_t)$	GPs' total medical cost of stage t related to e_t
u	GPs' medical effort cost coefficient
φ	The implicit reputation coefficient of GPs.
U_t	The total income of the principal community health institutions (Principal) of stage t
V_t	GPs' total deterministic revenue of stage t
F_t	GPs' retain utility of stage t
η	Bargain power of GPs
ξ	The uncertainty of GPs' medical performance without consideration of reputation

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2 **Declarations**

3 **Ethics approval and consent to participate**

4 Not applicable

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6 **Consent for publication**

7 I Binxin Zhu give my consent for information about myself to be published in Archives
8 of Public Health.

9

10 **Availability of data and material**

11 The data and material that support the findings of this study are available from the
12 corresponding author [Binxin Zhu], upon reasonable request.

13

14 **Competing interests**

15 The authors declare that they have no competing interests.

16

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20

21 **Authors' contributions**

22 Professor Zhiqiang Ma constructed the models; Binxin Zhu conceived and designed the
23 analysis, performed the analysis and wrote the paper.

24

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Figures

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Fig. 1 GPs two-stage dynamic reputation incentive mechanism model

Fig. 2 The effect of φ, τ on the size relationship of β_1^* and β^*

Fig. 3 The effect of φ, τ on the size relationship of e_1^* and e^*

Figures

Figure 1

GPs two-stage dynamic reputation incentive mechanism model

Figure 2

The effect of on the size relationship of β_1^* and β^* .

Figure 3

The effect of ϕ, τ on the size relationship of e_1^* and e^*