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PAYMENT SCHEMES INCENTIVE FOR IMPROVING PREVENTION AND TREATMENT IN CHRONIC DISEASES

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Abstract. *We examine the incentive effect of fee for service (FFS), bundled payment (BP) and pay for performance (PFP) on the prevention efforts of hospitals and patients. Models aimed at maximizing the utility of the patient and minimizing the benefits of medical association were established. The optimal solutions of prevention efforts of the patient, the prevention efforts of the community hospital and the treatment efforts of the specialized hospital under three payment schemes were calculated respectively. The prevention and treatment success rate and the cost of the funder under the three payment schemes were compared. The results show that the FFS has no incentive on the prevention efforts of hospitals and patients. When the penalty fee is small, the BP has higher prevention and treatment success rate than the PFP, but lowers the cost of the funder. When the penalty fee is large, the result is the opposite.*
Keywords: Bundled payment, Pay for performance, Fee for service, Chronic diseases, Prevention and treatment

1. **Introduction.** To improve the treatment quality of patients with chronic diseases and reduce medical cost, many hospitals have tried various methods to solve the problems of declining medical quality and rising medical cost, among which the more effective method is to change the payment scheme [1]. The rapid development of medical associations in China provides an opportunity for the reform of the payment scheme.

Many scholars have studied the effect of payment methods on hospital behavior. FFS refers to the way a patient receives a hospital's various medical services, based on which the hospital charges. The FFS not only fails to improve the quality of medical care but also increases the medical cost of the patients [2]. The BP is the same as the prospective payment system (PPS) [3], which means that the hospital collects a fixed total medical cost from the patient, and the hospital needs to bear all the medical expenses incurred by the patient. This fixed total medical cost includes not only the expenses incurred by the patient in the community hospital but also the expenses incurred by the patient in the specialized hospital. The BP is better than the FFS on the social welfare, patient readmission rate and patient waiting time in the public health care system [4]. Although the BP improves the hospital's efforts, it encourages the hospital to select mild patients for treatment and reject critically ill patients who may incur higher medical cost in order to maximize their benefits [5]. The BP improves the prevention and treatment success rate of chronic diseases [6]. The PFP determines how much the hospital charges the patient based on the outcome of the patient's treatment. This payment scheme can not only improve the prevention and treatment success rate of the hospital but also reduce

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the medical cost [7]. Some hospitals argue that they are being unfair by the PFP (or the BP), and chronic diseases' morbidity is extremely associated with the efforts of the patients [8]. If the patient does not follow the doctor's advice, the efforts of the hospital will not be effective. For example, the patient refused to accept the doctor's advice to take the medicine on time, and the patient continued to have bad habits. Existing studies generally only considered the prevention efforts of the hospital and the payment mechanism is mainly for general diseases which is a one-time payment problem. Hence, the gap in the study lies in that we consider not only the prevention efforts of the hospital but also the prevention efforts of the patient under three payment mechanisms. Patient with chronic diseases often has a variety of payment problems.

This paper has two contributions. Firstly, we consider the prevention efforts of the community hospital, the treatment efforts of the specialized hospital and the prevention efforts of the patient. In this paper, quantitative methods are used to study the influence of the total amount of the BP and the penalty fee of the PFP on the results. Secondly, the object of this payment scheme is a chronic disease patient. There are two stages: the stage of prevention and the stage of treatment. The community hospital and the specialized hospital should be regarded as a medical association to consider the relationship between prevention and treatment.

The rest of this paper is organized as follows. In Section 2, we describe the research problem. In Section 3, we derive prevention efforts in the equilibrium of all participants. We compare the prevention and treatment success rate and the cost of the funder. In Section 4, we do a numerical study. In Section 5, we get some concluding remarks.

2. **Problem Description.** In this section, we outline the model framework and some assumptions. We consider the medical association composed of a community hospital and a specialized hospital. The community hospital manages the patient with chronic diseases in the prevention stage. If the prevention fails, the patient will be transferred to a specialized hospital for treatment. After the treatment in the specialized hospital, the specialized hospital and the patient work together to make efforts for the patient's recovery. Through the treatment efforts of the specialized hospital and the prevention efforts of the patient, the result may be a complete success, or may not be completely cured. When the patient is not completely cured, the patient needs to be transferred to the community hospital for further care. The sequence of events is shown in Figure 1.

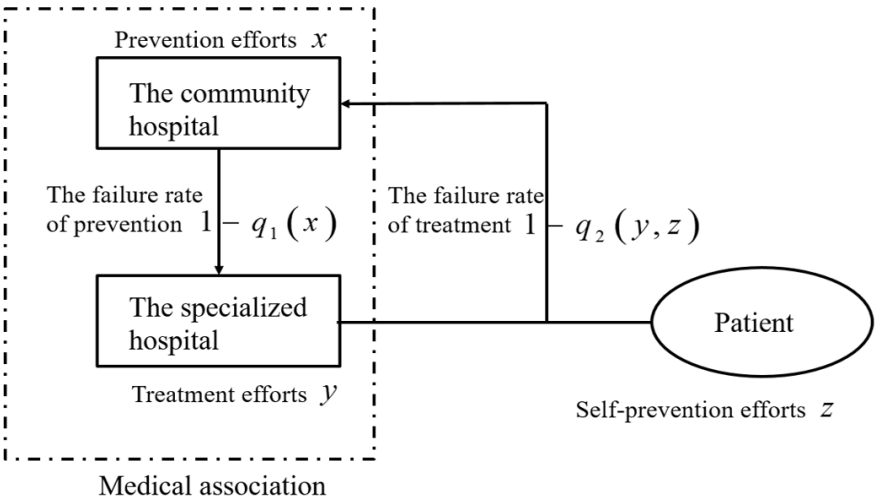

FIGURE 1. The process of prevention and treatment of chronic diseases in the medical association

The patient's goal is to minimize the cost and the medical association's goal is to maximize the benefits. Under the FFS, there is no incentive for the community hospital to produce prevention efforts and the specialized hospital to produce treatment efforts. Under the BP and the PFP, the community hospital manages the health status of the patient through prevention efforts to reduce the probability of complications. The prevention efforts of the community hospital generate cost, but they reduce the cost of referral and treatment for patients to the specialized hospital. Under the BP and the PFP, if the patient is transferred to the specialized hospital, how the specialized hospital takes appropriate treatment efforts and the patient takes appropriate prevention efforts to make decisions, because the specialized hospital may not completely cure the patient, the patient still needs to be transferred to the community hospital for care. There will be a new cost for both the medical association and the patient. The purpose of this paper is to compare the prevention and treatment success rate and the social welfare under the three payment mechanisms and analyze the impact of payment mechanism on the prevention efforts of hospitals and patients. The community hospital makes the first decision on prevention efforts, and then the specialized hospital makes the decision on treatment efforts, the patient makes decision on prevention efforts.

We assume the efforts of the specialized hospital and the patient complement each other. For example, the prevention efforts of the patient include following the doctor's dose, duration of medication, and regular door-to-door check-ups. x presents the prevention efforts of the community hospital, y presents the treatment efforts of the specialized hospital, and z presents the prevention efforts of the patient. The health state of the patient in the prevention stage is expressed by σ_1, and the patient's health state in the treatment stage is represented by σ_2, where $\sigma_1 \in [0,1]$ and $\sigma_2 \in [0,1]$. $\sigma_i = 1$ $(i = 1,2)$ indicates that the patient is healthy and $\sigma_i = 0$ $(i = 1,2)$ indicates that the patient is ill. The patient's health status is mainly affected by the prevention efforts of the patient and hospital. This type of complementarity between the patient and the specialized hospital shows that both sides are making efforts to improve the patient's health status. More generally, in the study of the doctor-patient relationship, similar situations in the literature about the complementarity between the specialized hospital and patient efforts have also been studied in other areas [9]. A Cobb-Douglas production function is used to describe this complementary behavior in the literature because it is a commonly used, simple and widely accepted form of production function [10]. The patient's health status is assumed as follows:

$$\sigma_1 = x^{\alpha} \tag{1}$$

$$\sigma_2 = y^{\beta} z^{\gamma} \tag{2}$$

where $0 < \alpha < 1$, $0 < \beta < 1$, $0 < \gamma < 1$, $0 < \alpha + \beta + \gamma < 1$. α, β and γ respectively indicate the flexibility of the patient's health status relative to the prevention efforts of the community hospital, the treatment efforts of the specialized hospital and the prevention efforts of the patient [11].

We use ρ_1 to indicate the prevention success rate without the prevention efforts of the community hospital, ρ_2 to indicate the treatment success rate without the prevention efforts of the patient and the treatment efforts of the specialized hospital. It is assumed that the prevention success rate in the community hospital is $q_1(x)$ and there is a linear relationship between $q_1(x)$ and σ_1 [12].

$$q_1(x) = 1 - \rho_1(1 - \sigma_1) \tag{3}$$

The treatment success rate in the specialized hospital and the patient is $q_2(y,z)$, and there is a linear relationship between $q_2(y,z)$ and σ_2.

$$q_2(y,z) = 1 - \rho_2(1-\sigma_2) \tag{4}$$

We assume the prevention efforts cost of the community hospital is $c_1(x) = \frac{1}{2}k_1x^2$, the treatment efforts cost of the specialized hospital is $c_2(x) = \frac{1}{2}k_2y^2$, and the prevention efforts cost of the patient is $c_3(z) = \frac{1}{2}k_3z^2$. k_1, k_2 and k_3 respectively indicate the coefficient of the community hospital prevention efforts affecting the prevention cost of the community hospital, the coefficient of specialized hospital treatment efforts affecting the prevention cost of the specialized hospital and the coefficient of the patient prevention efforts affecting the prevention cost of the patient.

3. **Prevention Efforts in Equilibrium.** We assume the stage of prevention and treatment is independent. First, for giving the specialized hospital efforts y, the patient determines optimal efforts $z(y)$. Then, we derive the community hospital's equilibrium efforts and the specialized hospital's equilibrium efforts. The corresponding equilibrium solution can be obtained under different payment schemes (FFS, BP and PFP).

3.1. **The patient's problem.** The problem of the patient is to choose his prevention efforts z to minimize his cost. When the patient has complications and the treatment fails, the patient has a standard cost of the transfer fee and incur fee T_0. The prevention efforts of the patient and the prevention efforts of the specialized hospital impact the probability of patient have complications. Hence, the patient's expected cost is

$$\begin{aligned} c_p &= q_1(x)\cdot 0 + (1-q_1(x))\left[T_0 + \frac{1}{2}k_3z^2 + (1-q_2(y,z))T_0\right] \\ &= (\rho_1 - \rho_1x^\alpha)\left[T_0 + \frac{1}{2}k_3z^2 + \left(\rho_2 - \rho_2y^\beta z^\gamma\right)T_0\right] \end{aligned} \tag{5}$$

Proposition 3.1. *For a patient who protects himself, the patient selects the optimal prevention efforts as*

$$z(y) = \emptyset_1 y^{\frac{\beta}{2-\gamma}}$$

where $\emptyset_1 = \left(\frac{\rho_2 T_0 \gamma}{k_3}\right)^{\frac{1}{2-\gamma}}$.

3.2. **The hospital's problem.** To maximize the profit of medical association in chronic diseases, the community hospital selects its corresponding prevention efforts x and the specialized hospital selects prevention efforts y to maximize the medical association's payoff. In this section, we study the FFS, BP and PFP three payment mechanisms.

3.2.1. *Fee for service.* Under the FFS system, we assume the specialized hospital receives payoff ωT_1 and the community hospital receives payoff ωT_2. For a patient, the community hospital exerts prevention efforts x and the specialized hospital exerts prevention efforts y. The payoff of the medical association is

$$\begin{aligned} &\pi^{FFS}(x,y,z) \\ &= q_1(x)\left(-\frac{1}{2}k_1x^2\right) + (1-q_1(x))\left[\omega T_1 - \frac{1}{2}k_1x^2 - \frac{1}{2}k_2y^2 + (1-q_2(y,z))\omega T_2\right] \end{aligned} \tag{6}$$

Substituting the $q_1(x) = 1-\rho_1(1-x^\alpha)$, $q_2(y,z) = 1-\rho_2\left(1-y^\beta z^\gamma\right)$ into Formula (6), we have

$$\begin{aligned} \pi^{FFS}(x,y,z) = {} & (1-\rho_1+\rho_1x^\alpha)\left(-\frac{1}{2}k_1x^2\right) \\ & + (\rho_1-\rho_1x^\alpha)\left[\omega T_1 - \frac{1}{2}k_1x^2 - \frac{1}{2}k_2y^2 + \left(\rho_2 - \rho_2y^\beta z^\gamma\right)\omega T_2\right] \end{aligned} \tag{7}$$

Proposition 3.2. *Under the FFS, the optimal prevention efforts of the community hospital, the optimal treatment efforts of the specialized hospital and the optimal prevention efforts of the patient are respectively equal to*

$$x^{FFS} = 0, \quad y^{FFS} = 0, \quad z^{FFS} = 0.$$

3.2.2. *Bundled payment.* Under the BP, the funder gives a fixed amount R for the medical association. For a patient, the community hospital exerts prevention efforts x and the specialized hospital exerts prevention efforts y to maximize the profit of the medical association. The payoff of the medical association is

$$\begin{aligned}&\pi^{BP}(x,y,z)\\ &= R - q_1(x)\left(\frac{1}{2}k_1x^2\right) - (1-q_1(x))\left[T_1 + \frac{1}{2}k_1x^2 + \frac{1}{2}k_2y^2 + (1-q_2(y,z))T_2\right] \end{aligned} \tag{8}$$

Proposition 3.3. *Under the BP, the optimal prevention efforts of the community hospital, the optimal treatment efforts of the specialized hospital and the optimal prevention efforts of the patient are respectively equal to*

$$x^{BP} = N^{\frac{1}{\alpha}}, \quad y^{BP} = \emptyset_1^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2 T_2^{\frac{2-\gamma}{4-2\beta-2\gamma}}, \quad z^{BP} = \emptyset_1^{\frac{4-2\gamma-2\beta+\beta\gamma}{4-2\beta-2\gamma}}\emptyset_2^{\frac{\beta}{2-\gamma}} T_2^{\frac{\beta}{4-2\beta-2\gamma}},$$

where $N = \left\{\dfrac{\rho_1\alpha\left[T_1+\emptyset_1^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2^{\frac{2\beta}{2-\gamma}}T_2^{\frac{6-3\gamma-2\beta}{4-2\beta-2\gamma}}\left(\frac{1}{2}k_2\emptyset_2^{\frac{4-2\gamma-2\beta}{2-\gamma}}T_2^{\frac{\gamma+2\beta-2}{4-2\beta-2\gamma}}-\rho_2\right)+\rho_2T_2\right]}{k_1}\right\}^{\frac{\alpha}{2-\alpha}}$ *and* $\emptyset_2 = \left[\frac{2\beta\rho_2}{k_2(2-\gamma)}\right]^{\frac{2-\gamma}{4-2\beta-2\gamma}}$.

3.2.3. *Pay for performance.* Under the PFP, if the treatment fails, the funder will give the medical association a penalty fee p. We assume the specialized hospital receives payoff ωT_1 and the community hospital receives payoff ωT_2, where $\omega > 0$. Hence, the community hospital will choose the optimal prevention efforts and the specialized hospital will choose optimal prevention efforts. For a patient, the community hospital exerts prevention efforts x and the specialized hospital exerts prevention efforts y to maximize the profit of the medical association.

$$\begin{aligned}\pi^{PFP}(x,y,z) = q_1(x)\left(-\frac{1}{2}k_1x^2\right) + (1-q_1(x))\Big[&\omega T_1 - \frac{1}{2}k_1x^2\\ &- \frac{1}{2}k_2y^2 + (1-q_2(y,z))(\omega T_2 - p)\Big]\end{aligned} \tag{9}$$

Proposition 3.4. *Under the PFP, the optimal prevention efforts of the community hospital, the optimal treatment efforts of the specialized hospital and the optimal prevention efforts of the patient are respectively equal to*

$$\begin{aligned}x^{PFP} &= 0,\\ y^{PFP} &= \emptyset_1^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2(p-\omega T_2)^{\frac{2-\gamma}{4-2\beta-2\gamma}},\\ z^{PFP} &= \emptyset_1^{\frac{\beta\gamma+4-2\beta-2\gamma}{4-2\beta-2\gamma}}\emptyset_2^{\frac{\beta}{2-\gamma}}(p-\omega T_2)^{\frac{\beta}{4-2\beta-2\gamma}}.\end{aligned}$$

Proposition 3.5. *Let*

$$f_1 = \frac{1}{2}k_1N^{\frac{2}{\alpha}} + (\rho_1 - \rho_1N)\times\left[T_1 + \frac{1}{2}k_2\left(\emptyset_1^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2T_2^{\frac{2-\gamma}{4-2\beta-2\gamma}}\right)^2\right.$$

$$+T_2\left(\rho_2-\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2{}^{\frac{2\beta}{2-\gamma}}T_2{}^{\frac{\beta}{2-\beta-\gamma}}\right)\Bigg],$$

$$f_2=\omega T_1-\frac{1}{2}k_2\left(\emptyset_1{}^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2(p-\omega T_2)^{\frac{2-\gamma}{4-2\beta-2\gamma}}\right)^2$$

$$-(p-\omega T_2)\left(\rho_2-\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2{}^{\frac{2\beta}{2-\gamma}}(p-\omega T_2)^{\frac{\beta}{2-\beta-\gamma}}\right),$$

$$f_3=\rho_1\left(\omega T_1+\rho_2\omega T_2\right).$$

We assume $f_2 < f_3$, and then the profit of the medical association under different payment mechanisms satisfies following relationships.

1) If $R \le f_1+f_2$, then $\pi^{BP} \le \pi^{PFP} < \pi^{FFS}$.

2) If $f_1+f_2 < R < f_1+f_3$, then $\pi^{PFP} < \pi^{BP} < \pi^{FFS}$.

3) If $R \ge f_1+f_3$, then $\pi^{PFP} < \pi^{FFS} \le \pi^{BP}$.

Proposition 3.5 states that 1) the PFP is always lower than the FFS on the profit of the medical association; 2) when the total fee under the BP is small, the BP is the smallest of the three payment mechanisms on the profit of medical association; when the total fee under the BP is large, the BP is the largest of the three payment mechanisms on the profit of medical association.

By increasing the total amount of the BP, more patients can choose the total payment mechanism for prevention in the community hospital.

3.3. **The funder's problem.** In this part, we want to know which payment mechanism is suitable for the funder.

We intend to minimize the cost of funder C_f under different payment schemes (FFS, BP and PFP). The cost of the funder function is defined as the sum of the funder pay to the medical association and the patient's transfer fee. We compare the prevention and treatment success rate and the cost of funder under different payment schemes (FFS, BP and PFP).

Proposition 3.6. *Under the FFS, the funder's cost is*

$$C_f{}^F = R+\rho_1\left(T_0+\rho_2T_0\right).$$

Proposition 3.7. *Under the BP, the funder's cost is*

$$C_f{}^B = R+(\rho_1-\rho_1N)\Bigg[T_1+\frac{1}{2}k_2\left(\emptyset_1{}^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2T_2{}^{\frac{2-\gamma}{4-2\beta-2\gamma}}\right)^2$$

$$+T_2\left(\rho_2-\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2{}^{\frac{2\beta}{2-\gamma}}T_2{}^{\frac{\beta}{2-\beta-\gamma}}\right)\Bigg]$$

Proposition 3.8. *Under the PFP, the cost of funder is*

$$C_f{}^P = R+\rho_1\left[T_0+\left(\rho_2-\rho_2\emptyset_1{}^{\gamma}\left(\emptyset_1{}^{\frac{2\gamma-\gamma^2}{4-2\beta-2\gamma}}\emptyset_2(p-\omega T_2)^{\frac{2-\gamma}{4-2\beta-2\gamma}}\right)^{\frac{\beta}{2-\gamma}}\right)T_0\right].$$

3.4. **Discussion to the first-best.** We have a plan to compare payment schemes from two key criteria: 1) the prevention and treatment success rate; 2) the cost of the funder.

Proposition 3.9. *Under the three payment mechanisms, the relationship between the prevention and treatment success rate is as follows:*

1) $q_1{}^{FFS} = q_1{}^{PFP} \le q_1{}^{BP}$.

2) If $\omega T_2 < p < (\omega+1)T_2$, *then* ${q_2}^{FFS} < {q_2}^{PFP} < {q_2}^{BP}$; *if* $(\omega+1)T_2 \le p$, *then* ${q_2}^{FFS} < {q_2}^{BP} \le {q_2}^{PFP}$.

By increasing the marginal benefit rate of the medical association, it will increase the fee for the patient to choose the FFS and the PFP, thus motivating more patients to choose the BP. It is beneficial for more patients to choose prevention in the community hospital.

Proposition 3.10. *Let* $\left[\frac{\rho_{2-}\left(\rho_2-\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2{}^{\frac{2\beta}{2-\gamma}}T_2{}^{\frac{\beta}{2-\beta-\gamma}}\right)(1-N)-N}{\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}}\right]^{\frac{\beta}{2-\beta-\gamma}} < T_2$.

1) If $\omega T_2 < p \le \omega T_2 + \left[\frac{\rho_{2-}\left(\rho_2-\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}\emptyset_2{}^{\frac{2\beta}{2-\gamma}}T_2{}^{\frac{\beta}{2-\beta-\gamma}}\right)(1-N)-N}{\rho_2\emptyset_1{}^{\frac{2\gamma-\gamma^2}{2-\beta-\gamma}}}\right]^{\frac{\beta}{2-\beta-\gamma}}$, *then* ${C_f}^P \le {C_f}^P < {C_f}^F$.

2) If $p > (\omega+1)T_2$, *then* ${C_f}^P < {C_f}^B < {C_f}^F$.

By decreasing the marginal benefit rate of the medical association, it is beneficial for the funder to reduce medical expenses.

4. **Numerical Study.** The prevention efforts of the community hospital impact the patient's health status. We compare different payment schemes (FFS, BP and PFP) as follows: 1) the prevention efforts of specialized hospital under three payment schemes, 2) the prevention efforts of patient under three payment schemes, 3) the treatment success rate under three payment schemes. The experimental results are shown in Figure 2.

To derive the model parameters reasonably estimated in this paper, we depend on [5]. We set the following values: $\rho_1 = 0.4$, $\rho_2 = 0.5$, $T_0 = 2000$, $T_1 = 4000$, $T_2 = 16000$, $R = 50000$, $k_1 = 4000$, $k_2 = 2400$, $k_3 = 3000$, $\omega = 0.25$, $\alpha = 0.1$, $\beta = 0.3$, $\gamma = 0.5$, and $p \in [16000, 24000]$.

Figure 2(a) states that the specialized hospital exerts no prevention efforts under the FFS. Figure 2(a) also shows that the specialized hospital exerts prevention efforts on patient under the BP and the PFP. When the penalty fee p is small, the BP is higher than the PFP on the specialized hospital's prevention efforts level. When the penalty fee p is large, the result is opposite.

Figure 2(b) reveals that the patient exerts no prevention efforts under FFS. Figure 2(b) also shows that the patient exerts prevention efforts on patient under the BP and the PFP. When the penalty fee p is small, the BP is higher than the PFP on the patient's prevention efforts level. When the penalty fee p is large, the result is opposite.

Figure 2(c) shows that the FFS is always lowest on the treatment success rate. When the penalty fee p is small, the BP is higher than the PFP on the treatment success rate. When the penalty fee p is large, the result is opposite.

5. **Conclusions.** We explain the impact of different payment schemes on the prevention and treatment success rate of chronic diseases, the benefit of the medical association, and the cost of the funder, and then we derive some conclusions.

From the medical association's point, we find the fact as follows: 1) the FFS is always highest on the medical association's profit; 2) when the penalty fee is small, the BP is higher than the PFP on the medical association's profit; when the penalty fee is large, the result is the opposite. From the funder's point, we find the fact as follows: 1) when the penalty fee is small, the BP is more advantageous than PFP on the treatment success rate and the cost of the funder; when the penalty fee is large, the result is opposite; 2)

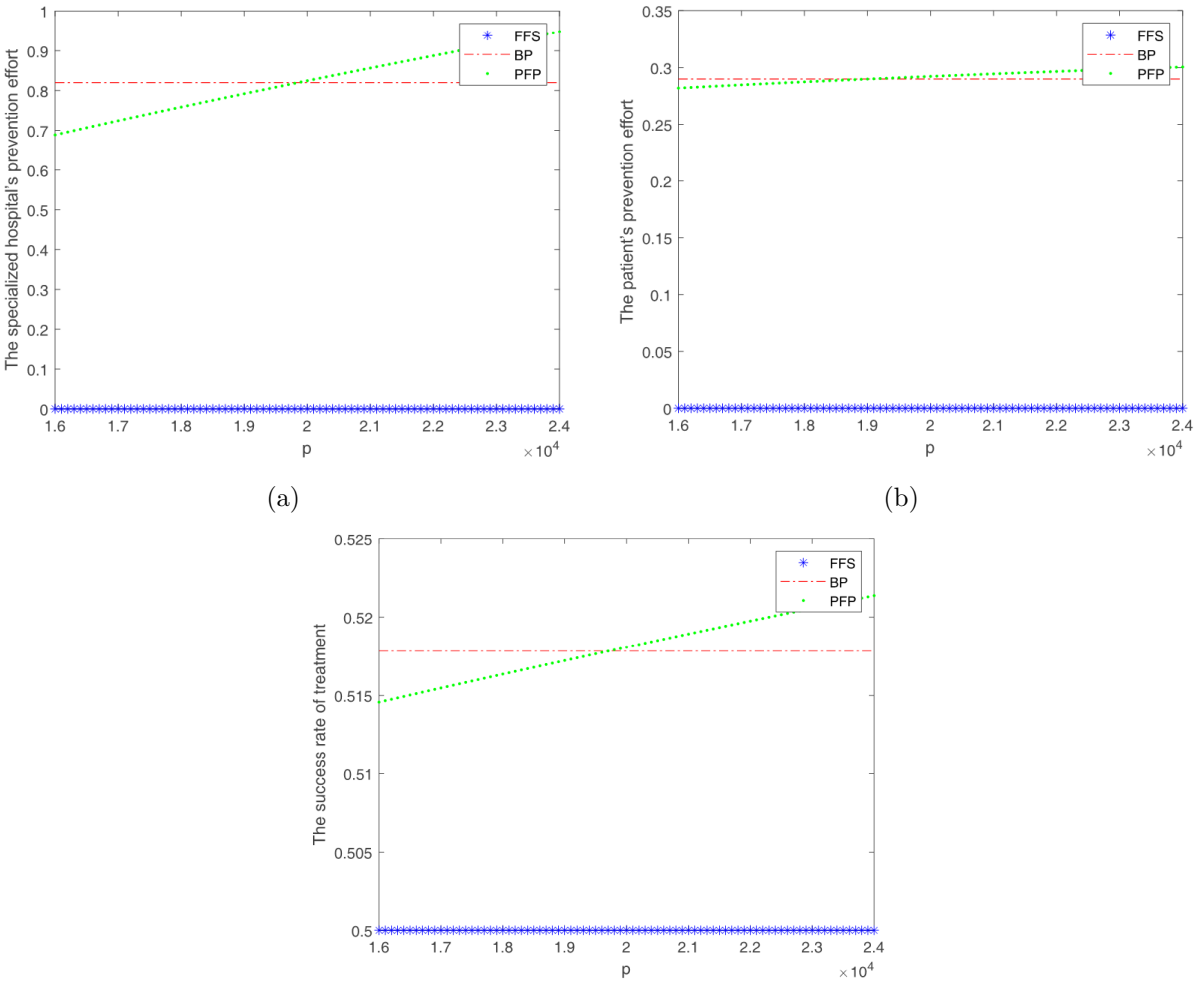

FIGURE 2. The effect of penalty fee on prevention efforts of specialized hospital, prevention efforts of patient and the treatment success rate

the FFS is always highest on the cost of funder but the lowest on the prevention and treatment success rate.

Hence, by decreasing the total amount of the BP and increasing the marginal benefit rate of the medical association, it motivates more patients to choose the BP. It is beneficial for more patients to choose prevention in the community hospital. By decreasing the marginal benefit rate of the medical association, it is beneficial for the funder to reduce medical expenses.

There is a limitation in our study, which provides a possible direction for the next research work. We did not consider the impact of prevention efforts in the community hospital and the specialized hospital, and efforts of patient on a health status of the patient in a model.

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