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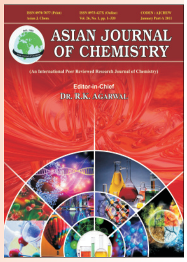

Medical Optimal Payment Mechanism Based on Principal-Agent Theory

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In order to improve the impact of ex anti asymmetric information on the efficiency of medical insurance transactions, we apply the principal-agent theory to curable diseases for establishing a kind of Medicare transaction contract model considering that the types of agents are discrete or continuous. Based on the principle of maximizing the effectiveness of the principal, the model enables an agent to show its real technical level of medical services by selecting its favorite and corresponding contract so as to increase the insurance company's expected utility. It is concluded that under the conditions of asymmetric information, the higher the technical level of medical services is, the lower the marginal cost is and that both the number of policy holders and the payment will increase, at least not decrease. Furthermore, compared with the conditions of symmetric information, there are downward distortions in the number of policy holders for all types of agents except the highest technical type and all types of agents can obtain strictly positive information rent except the lowest technical type. Therefore, under asymmetric information, the sub optimal contracts designed by our model can suppress the lower technical types of agents while encourage the higher technical types of agents, which means this model can maximize the expected utility of principal on the participation and incentive compatibility constraints of agents under asymmetric information.

Keywords: Ex anti asymmetric information, Moral risk, Principal-agent, Adverse selection, Information rent.

INTRODUCTION

In health insurance market, doctors are very likely to provide excessive medical services (such as unnecessary hospitalization, a needless high-cost instrument check, more drugs and many expensive drugs, *etc*.) for more profits. The patients with health insurance do not have incentives to resist the excessive services and some may even ask for them. The phenomenon is called consumer-provider collusion[1]. Because the ex post information between insurance company and doctors or patients is asymmetric, the insurance company may suffer from huge loss, which is the so-called moral hazard problem[2].

The problem occurs mainly because of the common post-pay system that insurance companies pay insurance expenses to the hospitals according to the ex post hospital bills. Many empirical evidences have confirmed the correlation between post-pay system and higher cost at national, organizational or individual levels[3-5].

In order to effectively prevent the problem from post-pay system, there are two main approaches: demand-side cost sharing (patients, *e.g*., co-insurance) and supply-side cost sharing (providers, *e.g*., prospective payment system). Some studies imply that the latter is more effective[6,7], so we adopt the prospective payment system (PPS) in this paper. In the PPS, insurance company pays a fixed cost to the health care providers in advance and the doctors should bear additional costs of excessive services without any associated gains. Based on the rational premise, the doctors will have no incentive to provide excessive services. Some studies show that the PPS can obviously reduce average hospital length of stay and thus lower the costs[8-10].

However the prospective payment system can not completely solve all the problems under asymmetric information, especially the specific method by which insurance company pays fairly to different health care providers[11-13]. Under ex anti asymmetric information, the insurance company does not know the types of providers in advance and the higher technical types of providers always disguise themselves as the lower. If the company still, respectively provides all types of providers with the optimal payment contracts according to symmetric information, only poor contracts with low utility[1] will be executed, while good contracts with high utility will withdraw from the market, which is a unique form of adverse selection[14].

To analyze and solve the adverse selection problem, the principal-agent theory is introduced[15-20]. The principal should build the mechanism of rewards and punishments to motivate agents to take action beneficial to principal through observed information. It depends on one maximization utility function and two constraints: participation constraint and incentive compatibility constraint. The former means for an agent, the expected utility of accepting the contract should not be less than the maximum expected utility (reservation utility) of not accepting the contract and the latter means the expected utility of the action which is beneficial to the principal should not be less than the utility of any other action. Thus, the problem of disguise will not exist.

The theory has been successfully implemented into the principal and agent problem of product manufacturing to build sub optimal model for different types of agents[21]. Enlightened by this, we transform the model and apply it into the field of health insurance to avoid adverse selection brought by the PPS, namely to screen technical types of health care providers. In our model, the insurance company is the principal and the health care providers (hospitals) are agents.

So from the perspective of insurance company, this paper establishes a Medicare transaction mechanism model under ex ante asymmetric information between insurance company and health care providers based on the PPS. The main contributions of this paper can be outlined as follows: The model can screen technical types of agents and guarantee that the higher types of agents get more policy holders and payment to improve the efficiency of the PPS. Except that the highest type of agent does not have the distortion in the number of policy holders, other types of agents have downward distortions under asymmetric information. Except that the lowest type of agent gets 0 rent, other types of agents obtain the strictly positive information rent. The suboptimal contracts built by our model can make a Pareto improvement.

Medicare transaction contracts for discrete technical types of agents: Firstly for modeling, four assumptions are given as follows: The diseases are curable and the treatment outcome can be easily observed. The technical level is determined by the medical cost, namely, low cost means high technical level, while high cost means low technical level. Here we suppose that the marginal cost of all agents is fixed[2]. The health insurance company controls the power to assign policy holders to the hospitals, *i.e.* the company can appoint policy holders to which hospital. The form of payment is the prospective payment system. The medical resources are limited and the insurance company must seek medical services from all technical types of hospitals to meet the demand, which can be seen in Fig. 2. If the high technical type of agents can meet the demand already, the insurance company only needs to offer the contract A* and the low type of agents will withdraw because the contract brings negative utility to them.

In this paper, the hospitals (agents) are committed by the health insurance company (principal) to provide the policy holders n with medical services. The principal's utility is $u(r_0x_0n)$, where x_0 is the insurance premium paid by policy holders and r_0 is the expected rate of return of the company, satisfying $r > 1$[3]. Besides, $u'(\cdot) > 0$, $u''(\cdot) < 0$ and $u(0) = 0$, which means the marginal value of the insurance policy is positive and strictly decreases with the increase in the number of the policy holders assigned by the principal.

In the principal-agent model of adverse selection, it is the marginal cost rather than the fixed cost of the agents that influences the optimization of the objective function, so this study focuses on the marginal cost, such as disposable surgical equipment, appliances and drugs. Generally, the fixed cost can be set to 0, such as the reusable medical equipment and plant of the hospitals.

For curable diseases whose treatment outcome can be easily observed, higher technical level means lower marginal treatment cost. Under asymmetric information, the principal does not know the technical level and marginal cost of the agents, but knows that the marginal cost can be classified into two types: $\theta \in \Theta = \{\underline{\theta}, \bar{\theta}\}$. The high technical level corresponds with low cost and low level corresponds with high cost $\underline{\theta}$, satisfying $\Delta\theta = \bar{\theta} - \underline{\theta} > 0$. Besides, the principal also knows the distribution of the agents. The proportions of the agents of $\underline{\theta}$ and $\bar{\theta}$ are, respectively λ and $1 - \lambda$, satisfying $0 < \lambda < 1$. Supposing n denotes the number of policy holders assigned by the principal to the agents and that represents the payment, then the principal aims to design a set of contracts { $(\underline{t}^*, \underline{n}^*)$; $(\bar{t}^*, \bar{n}^*)$} to motivate the two types of agents to reveal their own actual cost. Namely, the contracts can screen the different types of agents and eventually maximize the objective utility function of the principal.

Supposing p_0 is the average probability of illness of policy holders and that the agents are risk neutral, then the utility function of the agents is as follows:

$$U = t - \theta p_0 n \quad (1)$$

where t is prepaid by the insurance company to the hospitals and $\theta p_0 n$ is the expected cost of the hospitals. Here, the reservation utility of hospitals is set to 0 for simplification.

The objective utility function of the principal is as follows:

$$V = u(r_0 x_0 n) - t \quad (2)$$

Case of symmetric information: When the information is symmetric, the insurance company knows the technical types of hospitals, so the participation constraints can be expressed as follows:

$$\underline{t} - \underline{\theta} p_0 \underline{n} \geq 0 \quad (3)$$

$$\bar{t} - \bar{\theta} p_0 \bar{n} \geq 0 \quad (4)$$

The company needs to maximize the objective function (2) under the constraints of (3) and (4). When the marginal utility of the principal equals the marginal cost of the agent, the optimal number of policy holders assigned to the agents can be achieved. In other words, if the first-order conditions, $u'(r_0 x_0 \underline{n}^*) = \underline{\theta} p / r_0 x_0$ and $u'(r_0 x_0 \bar{n}^*) = \bar{\theta} p / r_0 x_0$, are satisfied, the principal's utility is maximal and the agents' reservation utility is 0. Since $u'' < 0$ and $\bar{\theta} > \underline{\theta}$, the optimal number will satisfy $\underline{n}^* > \bar{n}^*$, namely, high technical type of agents get more policy holders than the low type.

In Fig. 1, the two families of mutually parallel lines are the indifferent curves of the two types of the agents, where $\overline{U} = t - \overline{\theta}p_0\overline{n}$ and $\underline{U} = t - \underline{\theta}p_0\underline{n}$, the slopes of which are, respectively $\overline{\theta}$ and $\underline{\theta}$, satisfying $\overline{\theta} > \underline{\theta}$. Thus, the indifferent curves of low technical type of agents are steeper than those of the high type and the two families intersect only once, which meets the single intersection property or Spence-Mirrlees conditions[21]. Obviously, the profit of agents increases when the lines move obliquely upwards.

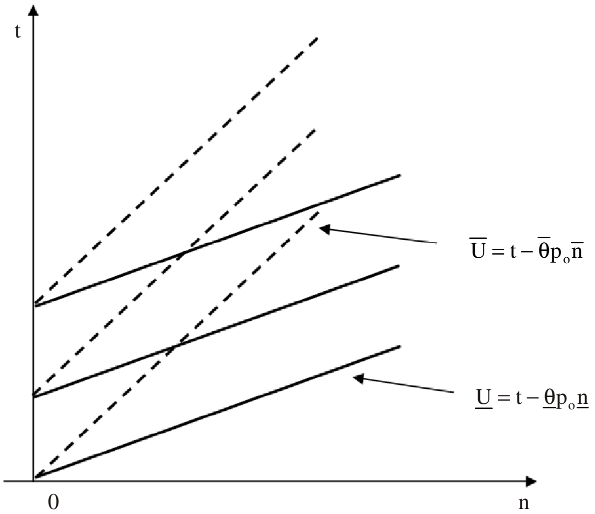

Fig. 1. Indifferent curves of high and low technical types of agents

In Fig. 2, A* and B* stand for the optimal contracts provided by the insurance company for high and low technical types of agents, respectively. At the two points, the indifferent utility curves of the principal are, respectively tangent to the indifferent zero-profit curves of the agents. The principal's utility increases with the distance further away from origin. So under symmetric information, A* brings greater utility for the principal than B* does and both the utilities are positive. However, under asymmetric information, the company does not know the technical types of the hospitals, so the high technical type of agents have incentives to disguise themselves as low technical type to choose the contract B* in order to get a positive rent (see the dotted line). In other words, only poor contracts with low utility will be executed, while good contracts with high utility will withdraw from the market, which is a unique form of adverse selection.

Case of asymmetric medicare information: Now assume that the marginal cost is the agents' private information. If the principal still provides this set of optimal contracts $\{(\underline{t}^*, \underline{n}^*), (\overline{t}^*, \overline{n}^*)\}$ for high and low types of agents for selection according to the symmetric information, high type of agents will disguise as the low type and select $(\overline{t}^*, \overline{n}^*)$ to obtain a positive utility rather than select $(\underline{t}^*, \underline{n}^*)$ to obtain zero utility. That is to say, the optimal contracts under incomplete information can not be implemented, or that the contracts are incentive incompatible under asymmetric information.

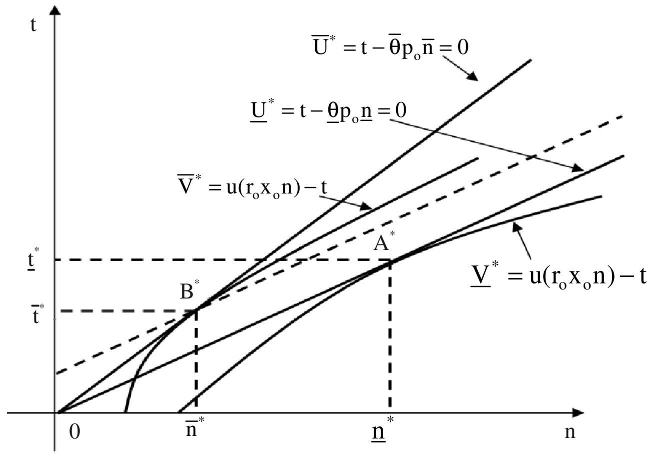

Fig. 2. Optimal set of contracts under symmetric information

Under asymmetric information, we design a new set of contracts $\{(\underline{t}, \underline{n}), (\overline{t}, \overline{n})\}$, respectively for high and low technical types of agents.

Firstly, the set of contracts should satisfy the participation constraints of the agents:

$$\underline{U} = \underline{t} - \underline{\theta}p_0\underline{n} \geq 0 \quad (5)$$

$$\overline{U} = \overline{t} - \overline{\theta}p_0\overline{n} \geq 0 \quad (6)$$

Secondly, the set of contracts should also satisfy the incentive compatibility constraints of the agents, which means that each type of agents will get no less net income (rent) from the contracts special for themselves than that from the contracts for another type of agents:

$$\underline{U} = \underline{t} - \underline{\theta}p_0\underline{n} \geq \overline{t} - \underline{\theta}p_0\overline{n} \quad (7)$$

$$\overline{U} = \overline{t} - \overline{\theta}p_0\overline{n} \geq \underline{t} - \overline{\theta}p_0\underline{n} \quad (8)$$

As the principal, the insurance company is to maximize his own expected net income under the constraints of (5), (6), (7) and (8):

$$\max\ \lambda(u(r_0x_0\underline{n}) - \underline{t}) + (1-\lambda)(u(r_0x_0\overline{n}) - \overline{t})$$

s.t (5), (6), (7), (8)

The principal's objective function can be equivalently changed into the following form:

$$\lambda(u(r_0x_0\underline{n}) - \underline{\theta}p_0\underline{n}) + (1-\lambda)(u(r_0x_0\overline{n}) - \overline{\theta}p_0\overline{n}) - (\lambda\underline{U} + (1-\lambda)\overline{U}) \quad (9)$$

The sum of the former two items is the expected return through configuration, *i.e.*, the total expected social welfare and the latter item represents the information rent, *i.e.*, the expected net income which should be paid to agents.

Proposition 1: When the set of contracts satisfies the incentive compatibility constraints, there must be $\underline{n} \geq \overline{n}$ and $\underline{t} \geq \overline{t}$.

Proof: Sum the incentive compatibility conditions (7) and (8) to get the inequality $\underline{n} \geq \overline{n}$ and further easily get the inequality $\underline{t} \geq \overline{t}$.

Proposition 1 shows under asymmetry information, the number of policy holders and payment to the high technical type of agents are both more than those to the low type. However, whether it holds or not under symmetric information is related to the curvature of the principal's indifferent curve.

Furthermore, low technical type of agents have no incentive to simulate the high type to select the contract (t, n), so the incentive compatibility constraint (8) is redundant and thus the participation constraints (5) and (6) and the incentive compatibility constraint (7) can be merged as follows for simplification:

$$\underline{U} \geq \overline{U} + \Delta\theta p_0 \overline{n} \quad (10)$$

$$\overline{U} \geq 0 \quad (11)$$

In the optimal case, the two constraints must be tight and we can obtain:

$$(\overline{t}^*, \overline{n}^*) \quad (12)$$

$$\overline{U} = 0 \quad (13)$$

Substitute the equalities (12) and (13) into the equality (9) and then the objective function can be simplified as:

$$\lambda(u(r_0x_0\underline{n}) - \underline{\theta}p_0\underline{n}) + (1-\lambda)(u(r_0x_0\overline{n}) - \overline{\theta}p_0\overline{n}) - \lambda\Delta\theta p_0\overline{n} \quad (14)$$

Proposition 2: Under asymmetric information, the set of optimal contracts has the following characteristics (the superscript SB denotes the suboptimal solution): $\underline{n}^{SB} = \underline{n}^*$, $\overline{n}^{SB} < \overline{n}^*$, $r_0x_0u'(r_0x_0\overline{n}^{SB}) = \overline{\theta}p_0 + \frac{\lambda}{1+\lambda}\Delta\theta p_0$ and $\underline{U}^{SB} = \Delta\theta p_0\overline{n}^{SB}$.

Proof: The first-order conditions about the suboptimal number of policy holders are:

$$r_0x_0u'(r_0x_0\underline{n}^{SB}) = \underline{\theta}p_0 \text{ or } \underline{n}^{SB} = \underline{n}^* \quad (15)$$

$$(1-\lambda)(r_0x_0u'(r_0x_0\overline{n}^{SB}) - \overline{\theta}p_0) = \lambda\Delta\theta p_0$$

or $$r_0x_0u'(r_0x_0\overline{n}^{SB}) = \overline{\theta}p_0 + \frac{\lambda}{1-\lambda}\Delta\theta p_0 \quad (16)$$

In the above (14), the rent is independent of $\underline{n}$, but dependent of $\overline{n}$. So compared with $u'(r_0x_0\underline{n}^*) = \underline{\theta}p/r_0x_0$, the number of policy holders assigned to the high type is not distorted, *i.e.*, $\underline{n}^{SB} = \underline{n}^*$; while compared with $u'(r_0x_0\overline{n}^*) = \overline{\theta}p_0/r_0x_0$, the number of policy holders assigned to the low type is distorted downwards, i.e., $\overline{n}^{SB} < \overline{n}^*$ ($u'' < 0$).

From (12), we can obtain:

$$\underline{U}^{SB} = \Delta\theta p_0\overline{n}^{SB} \quad (17)$$

In addition, from (5), (6), (12) and (13), we can calculate the suboptimal payments:

$$\underline{t}^{SB} = \underline{\theta}p_0\underline{n}^* + \Delta\theta p_0\overline{n}^{SB} \text{ and } \overline{t}^{SB} = \overline{\theta}p_0\overline{n}^{SB} \quad (18)$$

In Fig. 3, under asymmetric information, to prevent high type of agents to disguise as the low type, the incentive compatible contract (B*, C) is provided instead of (A*, B*) and high type of agents can obtain the information rent $\Delta\theta p_0\overline{n}^*$. However, the contract is still not optimal. When the line of the high type moves downwards in parallel, the rent of the high type and the optimal number of policy holders of the low type both decrease, which means that the insurance can reduce the information rent for the high type by cutting down the number of policy holders of the low type to maximize its expected utility. Thus under asymmetric information, (A^{SB}, B^{SB}) is the equilibrium sub optimal solution.

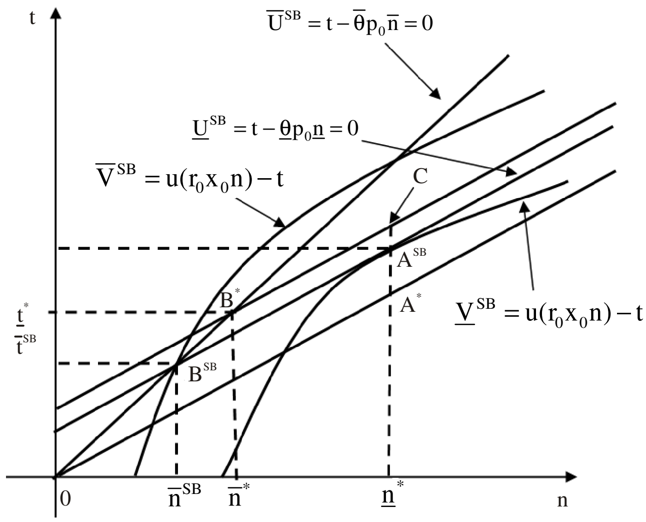

Fig. 3. Sub optimal set of contracts under asymmetric information

Proposition 3: Under asymmetric information, the insurance company's utility obtained from the suboptimal contracts for discrete types of agents is more than that from the contracts still according to the symmetric information condition, but less than that from the optimal contracts under symmetric information.

Proof: On one side, through the analysis above, under asymmetric information, if the principal provides the contracts still according to the symmetric information, all the agents will choose the contract $(\overline{t}^*, \overline{n}^*)$ for the low type. Notice that $(\overline{t}^*, \overline{n}^*)$ satisfies the participation and incentive compatible constraints (5), (6), (7) and (8) and suboptimal contract is the optimal solution of the model under asymmetric information. So it's obvious the insurance company's utility obtained from the suboptimal contracts is more than that from the contracts still according to the symmetric information.

On the other side, under asymmetric information, the high type of agents obtains positive information rent, while the rent is zero under symmetric information. Thus the principal's utility from the high type decreases. At the same time, the rent of the low type is still zero, but the number of policy holders decreases. Thus the principal's utility from the low type also decreases. So the insurance company's utility obtained from the suboptimal contracts is less than that from the optimal contracts under symmetric information.

Medicare transaction contracts for continuous technical types of agents: Now assume that the technical level and corresponding marginal cost of the agents are both continuous, namely, $\theta \in \Theta = [\underline{\theta}, \overline{\theta}]$, whose cumulative distribution function and distribution density are, respectively denoted by

$F(\theta)$ and $f(\theta)>0$, with the monotone hazard rate $\frac{d}{d\theta}\left(\frac{F(\theta)}{f(\theta)}\right)\geq 0$ (Bagnoli and Bergstrom, 1989). $t(\theta)$ and $n(\theta)$ represent the transfer payment and the number of policy holders, respectively, which are both differentiable to θ. Then the participation constraint is expressed as follows:

$$t(\theta)-\theta p_0 n(\theta)\geq 0 \quad (19)$$

Here, the incentive compatible constraint means the agent's income from the contract $\{t(\theta),n(\theta)\}$ provided specially for it is not less than that from the contract $\{t(\tilde{\theta}),n(\tilde{\theta})\}$ provided for the other agents, namely:

$$t(\theta)-\theta p_0 n(\theta)\geq t(\tilde{\theta})-\theta p_0 n(\tilde{\theta}) \quad (20)$$

The above incentive compatible constraint can be replaced by the first-order condition:

$$t'(\tilde{\theta})-\theta p_0 n'(\tilde{\theta})\big|_{\tilde{\theta}=\theta}=0\text{, namely, } t'(\theta)-\theta p_0 n'(\theta)=0 \quad (21)$$

As principal, the insurance company maximizes his own expected net income under the constraints (19) and (20) as:

$$\max\int_{\underline{\theta}}^{\bar{\theta}}(u(r_0x_0n(\theta))-t(\theta))f(\theta)d\theta$$

s.t (19), (21)

Proposition 4: When the set of contracts satisfies the incentive compatibility constraints, there must be $n'(\theta)\leq 0$ and $t'(\theta)\leq 0$.

Proof: From (20), we can get that:

$$t(\theta)-\theta p_0 n(\theta)\geq t(\theta')-\theta p_0 n(\theta')$$

$$t(\theta')-\theta' p_0 n(\theta')\geq t(\theta)-\theta' p_0 n(\theta)\text{, where } \forall\theta,\theta'\in\Theta$$

Sum the inequalities above and we can get that:

$$(\theta-\theta')p_0(n(\theta')-n(\theta))\geq 0$$

So $n(\cdot)$ must be non-incremental, *i.e.*, $n'(\theta)\leq 0$. And $t'(\theta)\leq 0$ according to (21).

Proposition 4 shows the higher the technical level is, the lower the marginal cost is and both the number of policy holders and the payment will increase, at least not decrease.

Proposition 5: Compared with the optimal contracts under symmetric information, the suboptimal contracts under asymmetric information have the following characteristics: Except that the highest technical level of medical service agent does not have the distortion in the number of policy holders, other types of agents have downward distortions, *i.e.*, $n^{SB}(\tilde{\theta})<n^*(\tilde{\theta})$, $\tilde{\theta}\in(\underline{\theta},\bar{\theta}]$, $\underline{n}^{SB}(\underline{\theta})=\underline{n}^*(\underline{\theta})$ and $r_0x_0u'(r_0x_0n^{SB}(\theta))=p_0(\theta+\frac{F(\theta)}{f(\theta)})$. And except that the lowest technical level of medical service agent gets 0 rent, other types of agents obtain the strictly positive information rent, *i.e.*, $U^{SB}(\theta)=p_0\int_{\theta}^{\bar{\theta}}n^{SB}(\tau)d\tau$ and $U(\bar{\theta})=0$. It is similar to the discrete case.

Proof: Let $U(\theta)=t(\theta)-\theta p_0 n(\theta)$ represent the rent. $U'(\theta)=t'(\theta)-p_0n(\theta)-\theta p_0 n'(\theta)=-p_0n(\theta)$, because $t'(\theta)-\theta p_0 n'(\theta)=0$ (21).

Then integrate the equality above:

$$U(\bar{\theta})-U(\theta)=-p_0\int_{\theta}^{\bar{\theta}}n(\tau)d\tau$$

Similar to the discrete type, only the participation constraint for the lowest technical type of agent works, *i.e.*, $U(\bar{\theta})=0$, so $U(\theta)=p_0\int_{\theta}^{\bar{\theta}}n(\tau)d\tau$. Namely, $U^{SB}(\theta)=p_0\int_{\theta}^{\bar{\theta}}n^{SB}(\tau)d\tau$ and $U(\bar{\theta})=0$. The second part of the proposition has been proved.

Then substitute $U(\theta)=p_0\int_{\theta}^{\bar{\theta}}n(\tau)d\tau$ into the objective function:

$$\int_{\underline{\theta}}^{\bar{\theta}}(u(r_0x_0n(\theta))-t(\theta))f(\theta)d\theta$$

And we can get:

$$\int_{\underline{\theta}}^{\bar{\theta}}(u(r_0x_0n(\theta))-\theta p_0n(\theta)-p_0\int_{\theta}^{\bar{\theta}}n(\tau)d\tau)f(\theta)d\theta$$

Change $\int_{\underline{\theta}}^{\bar{\theta}}(\int_{\theta}^{\bar{\theta}}n(\tau)d\tau)f(\theta)d\theta$ by integral subsection integration:

$$\int_{\underline{\theta}}^{\bar{\theta}}(u(r_0x_0n(\theta))-(\theta+\frac{F(\theta)}{f(\theta)})p_0n(\theta))f(\theta)d\theta$$

And we can get the derivative of $n(\theta)$, *i.e.*, the first-order condition about the suboptimal number of policy holders:

$$r_0x_0u'(r_0x_0n^{SB}(\theta))=p_0(\theta+\frac{F(\theta)}{f(\theta)}) \quad (22)$$

Notice that $\frac{d}{d\theta}(\frac{F(\theta)}{f(\theta)})\geq 0$ and $u''(\cdot)<0$, so $n^{SB}(\theta)$ is obviously degressive. Substitute $F(\underline{\theta})=0$ into (22) and we can get $n^{SB}(\tilde{\theta})<n^*(\tilde{\theta})$, $\tilde{\theta}\in(\underline{\theta},\bar{\theta}]$ and $\underline{n}^{SB}(\underline{\theta})=\underline{n}^*(\underline{\theta})$. Thus the first part of the proposition has also been proved.

Proposition 6: Under asymmetric information, the insurance company's utility obtained from the suboptimal contracts for continuous types of agents is more than that from the contracts still according to the symmetric information condition, but less than that from the optimal contracts under symmetric information.

Proof: Similar to the proof of proposition 3.

Application example: Through the market research, the cost function of medical service agents obeys uniform distribution, namely, $U[2000,6000]$. Then

$$f(\theta)=\begin{cases}\frac{1}{4000} & 2000\leq\theta\leq 6000\\ 0 & \text{Others}\end{cases}$$

and

$$F(\theta)=\begin{cases}\frac{\theta\text{-}2000}{4000} & 2000\leq\theta\leq 6000\\ 0 & \text{Others}\end{cases}$$

For the policy holders, the probability of illness in one-year insurance period is denoted by $p_0=0.0001$, the insurance premium per year is denoted by $x_0=10$ and the rate of return on investment of the insurance company is denoted by $r_0 = 1.06$. The utility function of the principal is $u(x) = x^{\frac{4}{5}}$. So $u(r_0 x_0 n(\theta)) = (10.6n(\theta))^{\frac{4}{5}}$ 2. The goal here is to verify the Theorems 4, 5 and 6.

Under symmetric information, all the agents obtain zero information rent, so $t^*(\theta) = \theta p_0 n^*(\theta)$. And $u'(rxn^*(\theta)) = \theta p/rx$.

So $n^*(\theta) = \frac{4.136885\times 10^{23}}{\theta^5}$, $t^*(\theta) = \frac{4.136885\times 10^{19}}{\theta^4}$

The expected net utility of the principal is:

$$V_1 = \int_{2000}^{6000} \frac{1}{4000}((10.6n^*(\theta))^{\frac{4}{5}} - t^*(\theta))d\theta = 1.037413\times 10^5$$

Under asymmetric information, if the insurance company provides the contracts still according to the symmetric information condition, all the agents will choose the contracts for the lowest technical type of agent.

The expected net utility of the principal is:

$$V_2 = \int_{2000}^{6000} \frac{1}{4000}((10.6n^*(\bar{\theta})^{\frac{4}{5}}) - t^*(\bar{\theta}))d\theta = 7980.101$$

Under asymmetric information, if the insurance company provides the contracts according to the model in this paper.

According to the first-order co ndition:

$$r_0 x_0 u'(r_0 x_0 n^{SB}(\theta)) = p_0(\theta + \frac{F(\theta)}{f(\theta)})$$

we can get $$n^{SB}(\theta) = \frac{1.292776\times 10^{22}}{(\theta - 1000)^5} \quad 3$$

$$n^{SB'}(\theta) = -\frac{6.46338\times 10^{22}}{(\theta-1000)^6} < 0 \quad 2000 \le \theta \le 6000$$

and $$t'(\theta) = \theta p_0 n^{SB'}(\theta) = -\frac{6.463380\theta\times 10^{18}}{(\theta-1000)^6} < 0$$

So it is consistent with Proposition 4.

Let $\Delta = n*(\theta) - n^{SB}(\theta)$, $\Delta' > 0$, $\Delta(2000) = 0$.

So $n^{SB}(\tilde{\theta}) < n^*(\tilde{\theta})$, $\tilde{\theta} \in (\underline{\theta}, \bar{\theta}]$ and $\underline{n}^{SB}(\underline{\theta}) = \underline{n}^*(\underline{\theta})$.

And

$$U^{SB}(\theta) = p_0 \int_{\theta}^{\bar{\theta}} n^{SB}(\tau)d\tau = \frac{1}{4000}\int_{\theta}^{6000}\left(\frac{1.292776\times 10^{22}}{(\tau-1000)^5}\right)d\tau > 0$$

So it is consistent with Proposition 5.

The expected net utility of the principal is:

$$V_3 = \int_{2000}^{6000} \frac{1}{4000}((10.6n^{SB}(\theta))^{\frac{4}{5}} - \left(\theta + \frac{F(\theta)}{f(\theta)}\right)p_0 n^{SB}(\theta))d\theta$$
$$= 53434.8$$

Table-1 presents the contrasts on the net utility in three cases, from which it can be seen that under asymmetric information, the suboptimal contracts can make a Pareto improvement over the contracts still according to symmetric information condition, but can not achieve the optimal results under symmetric information. So it is consistent with Proposition 6.

Conclusion

Based on the principal-agent theory, the suboptimal contracts built by our model can screen different technical types of medical service agents and make sure that insurance company cooperates more with the higher type so as to improve the efficiency of the PPS under asymmetric information. Through rigorous proof, three conclusions can be drawn for both discrete and continuous technical types of agents as follows:

First, under asymmetric information, the higher the technical level is, the lower the marginal cost is and both the number of policy holders and the payment will increase, at least not decrease.

Second, under asymmetric information, except that the highest technical level of medical service agent does not have the distortion in the number of policy holders, other types of agents have downward distortions. Except that the lowest technical level of medical service agent gets 0 rent, other types of agents obtain the strictly positive information rent.

Last but not least, under asymmetric information, the suboptimal contracts can make a Pareto improvement over the contracts still according to symmetric information condition, although they can not achieve the optimal results under symmetric information.

The model in this paper can maximize the expected utility of principal on the participation and incentive compatibility constraints of agents under asymmetric information. Also it can suppress the lower technical types of agents and encourage higher technical types of agents so as to solve adverse selection problem of the PPS faced by insurance company.

However, it must be pointed out that we assume the diseases are curable and the treatment outcome can be easily observed and further studies are still needed for the complicated and uncertain diseases. Besides, the model in this paper is single-period and multi-period model should be developed to make greater improvement

TABLE-1
CONTRASTS ON THE NET UTILITY IN THREE CASES

Three cases	The optimal contracts under symmetric information	The contracts still according to symmetric information under asymmetric information	The suboptimal contracts according to this model under asymmetric information
Net utility	103741.3	7980.101	53434.8
Utility increments compared with the second case	95761.2	0	45454.7
Profit increments compared with the second case	1684342	0	663702.5

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