Dynamic Effort Setting in the Principal-Agent Model

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Abstract

This study is going to find the optimal path of the agent's working effort in the principal-agent model. The research specially focuses on the physician service market, where the agent is also the expert. The physician behavior is modelled by the life time utility maximization setting with regard to the reputation consideration. Physicians' different responses under different payment systems will be compared and analyzed.

1 Introduction

Principal-agent relationship is very common in the labor industry. Particularly, in the medical and legal services, the seller is also the expert to determine what kind and how much service is needed for the principal. In physician-agent theory, physician is the informative agent for the patient, and his effort of giving health care services is unobservable to the patient.

Patients can infer physicians' unobservable effort from observed health outcome and the services they got more or less. This fact is especially true in the repeated relationship between the physicians and the patients, such as the chronic treatments. What's more, empirical work shows that consumers get information of the physicians' quality mainly from the word-by-mouth communication. They are most willing to take the advice from their friends, colleagues and neighbors. Thus, if the physicians want to continue the relationship with the patients and gain the reputation in the community, they would better give qualified health care services to their patients. Quality services mainly depend on physicians' working effort. Nonetheless, the effort is costly for the physicians, which gives a reason for physicians to shirk.

In this study, the physician is maximizing the discounted flow of his utility during his life time. The utility is a function of income, patient health and the reputation in each period. Reputation depends on the health status improvement of the patient, which depends on the physician input of the medical services and the effort. Reputation evolves all the time, and the past reputation will not disappear, instead, it exists in a depreciated form. Physician can also control the amount of medical services to boost his income.

This study is aimed to find the optimal path of the effort level and

number of medical services during the physician'e life time. At current study, the static model has been analyzed at first. The physician behavior under different payment system has been compared. The two period model has also been constructed to tell the process of the effort and medical services.

The related literature is presented in the following section. The model setting is given in section three. In section four, I analyze the static model at first. The two period model is given in section five. I draw some conclusions and point out the future study in the last section.

2 Background

Asymmetric information is one of the most important features in the principal agent model, which gives an opportunity for the agent to shirk. The quality of the health care market largely depends on the physician's working effort. In Hail (2002) paper, he defines "effort" as any activity which is beneficial to the patients but costly to the doctor. Additional effort, for example, may involve better bedside manner, shorter waiting time, more thorough preparation for a surgical procedure, substitution of more expensive or sophisticated procedures for simpler ones, or more intensive patient monitoring.

Knowing how physician's effort is allocated will help to set up compensation scheme to encourage physician to exert more effort. To my knowledge so far, the dynamic setting and numerical solution of the physician effort is very limited. Gaynor (1994) points out that the research of dynamic aspect of physician-patient relationship will be promising. The continuous relationship between physician and patients can limit the opportunistic behavior in agency relationships. Specifically, incorporating information transmission

among consumers to a marketwide reputation can be important.

In the prominent paper of McGuire (2000), the bayesian patients are assumed to tell the likelihood of the quality of the physician from the services they received and the health outcome they got. The patients' demand for the physician's services depends on this likelihood. Therefore, the physician's profit depends on this likelihood. The author argues that the unobserved inputs may complement or substitute for the contractible inputs. By setting the level of the noncontractible inputs, the physician can influence demand for the contractible ones. The author mentions that a payer can take advantage of a physician's ethical constraint by setting up a payment system that puts the physician in the position of being forced to take more effort to make sure the patient attains an acceptable outcome.

Pauly and Satterthwaite (1981) define the physician services as a "reputation" good. A reputation good is a product or service for which 1. sellers' products are differentiated, and 2. consumers' search among sellers is conducted primarily by asking relatives, friends, and associates for recommendations.

In my paper, I am going to relate the unobserved effort to observed physicians' personal reputation in a dynamic way to tell why and how the physician offers effort. Reputation not only depends in the patient health improvement but also the past reputation stock. The health improvement depends on the physician's medical services and effort input, which is controlled by the physician.

In Zweifel and Breyer (1997), they present a physician behavior model using time unit. The patients' total demand for medical services is also measured by the time. Therefore, the physician's working time should not less than the medical time he is demanded. I think the way to use time

measurement is very insightful, and it can make the model simplified. While their model is not set dynamically, and not considering the physician effort.

In the traditional industrial organization literature, there is huge literature about firms price and quantity setting to maximize profit with regard to the firm's reputation. Shapiro (1983) names the reputation as "goodwill". Consumers use the quality of products produced by the firm in the past as an indicator of present or future quality. Thus, a firms' decision to produce high quality items is a dynamic one: the benefits of doing so accumulated in the future via the effect of building up the reputation.

Reputation is rarely constructed into the individual bahavior model, especially in the physician market. Wolinsky (1993) examines the "expert agent", who are the most knowledgable person in the services. He points out that there are two factors will discipline the agents: the consumers' search for multiple opinions; and agent's reputation consideration. His conclusion is that experts are more likely to be disciplined by customer search or by reputation according to whether these costs are lower or higher.

In my study, the reputation is one of the argument in the physician utility function. Physicians need to increase the quality supplied, if they want to boost the demand for their services. Since the quality of the medical services are not observed, the demand for the health care services is assumed to depend on the perceived quality, which is the reputation of the physician. My model will set up a dynamic process describing the reputation variable that builds up over time. There are two extreme strategies for a typical physician. On the one hand, he can choose to induce a lot medical services, if the disutility from the inducement is not too much, and give low effort to each service. In this way, he can earn the current income, giving up the future market. On the other hand, the physician may want to exert effort

today and offering the optimal medical services for patients' health. He may not gain too much income and also receive disutility from the effort, but he chooses to win the market in the future. Effort itself does not give income to the physician, but effort helps to win the reputation and the market, increase the "income" through higher demand. We are going to find the optimal dynamic strategy of the combination of the services and the effort in the physician's life cycle under different payment schemes.

3 Research Description

The answer I am looking for is the optimal path of the services x_t and effort e_t, $((x_{i1}, e_{i1})$, (x_{i2}, e_{i2}),..., $(x_{iT}, e_{iT}))$, a typical physician i will control to maximize his life time utility.

Some Industrial Organization literature tells us that if the time horizon is finite, firms's optimal strategy is to shirk at the end of the time to win the profit, which is called "milk the reputation". In our case, although physicians are still considering patients' health, they are also likely to shirk at the end of their career life. [1] Thus, in this study the reputation of the last period is also considered as the legacy for the physician. Different physicians can put different weights on this legacy. The physician will not decrease the effort level too much, if he put large weight on the reputation when he left the career. [2]

[1] Maybe some optimal contract can be designed to avoid from shirking, however, my study focuses on the physician behavior given the payment system, contract design is out of reach of this paper.

[2] I still hypothesize that the effort path will increase to the peak and then decrease. Some physicians may work hard at the first, and then shirk since they have gained enough reputation.

Since different payment systems give physicians different incentives to work hard, physicians will behave differently according to different scheme. I am going to analyze and compare the physician behavior under different payment systems: the fee-for-service, the capitation, and the combination of the two systems.

The model under the FFS can be written as the following:

$$\begin{aligned} max_{i_t,e_t} \quad & \sum_{t=0}^{T} \beta^t U(y_t, h_t, R_t, i_t, e_t) + qR_{T+1} && (1) \\ s.t.\ \ y_t \quad = \quad & n(R_t)(P - C)(x_t^* + i_t) && (2) \\ R_t \quad = \quad & \rho R_{t-1} + f(h_t, h_{0t}) && (3) \\ h_t(h_{0t}, x_t^* + i_t, e_t) \quad & h_{0t}, x_t^*, R_0 \ are\ given. && (4) \end{aligned}$$

where y is the income, R stands for the reputation, i is the inducement level, h is patient's health status, e is the effort level.

3.1 Income equation

First of all, I would like to explain the first physician income equation $y_t = n(R_t)(P - C)(x_t^* + i_t)$, where y_t is the physician's income at t. The income equals to the number of medical services $x_t^* + i$ for each patient times the income $P - C$ for each services times the number of the patients $n(R_t)$. For each service, the physician can get the payment P and cost C. I assume both of them are constant for simplification.

The number of the patients n depends on the physician's reputation. The more reputation the physician has, the more patients he will have. This is consistent with the argument of Dranove and White (1987) that if repeat purchases constitutes a significant part of a physician's business, refusal to buy services in the future may be an effective disciplining device. Thus, a

physician who produces low quality services and offers low effort may find himself without any customers. On the contrary, a high-quality provider may be able to create a "brand" identity to capitalize on reputation effects.

For any given period, the patient's initial health status is given. Accordingly, the physician knows what is the optimal level of medical services x_t^* that the patient needs. Here the optimal means the best level of medical services for the patient's health. Physician usually can control the number of the medical services, which might not be the optimal one for the patient's health, which is called "physician induced demand" in the health economics literature. Suppose the optimal level of services at time t is x_t^*, instead of control the total medical services $x_t(= x_t^* + i_t)$, the physician control the inducement level i_t, which measures the difference between the optimal level. It is as same to control the x_t as to control the i_t knowing the optimal level x_t^*. To construct in this way, I can enter the inducement into physician's utility function. For any given inducement, there will be disutility for the physician. The larger the difference to the optimal level, the higher the disutility.

Generally, we can construct the income equation as $y_t = n(R_t)(r + (P - C)(x_t^* + i_t))$. Here, if r is zero and $p > 0$, the payment system is fee-for-service, where r stands for the payment for each enrolled patient the doctor has. If p is zero and $r > 0$, the system is capitation. [3] [4]

[3]Some payment methods also offer bonus and compensations. In my basic model, I do not include these extra income.

[4]For this moment, I assume that p is exogenously given. Later on, I may assume that physician can control p.

3.2 Reputation construction

Income of time t relates to the physician's reputation accumulation. In the second constraint, R_t stands for the reputation at time t. It equals to the summation of depreciated stock reputation at the previous period, and a function of current and initial patient health status. Effort will increase reputation through the improvement of the patient's health. Because of the information diffusion, physician's effort can help him win the reputation and attract the patients tomorrow. The physician's effort today won't disappear suddenly, it will contribute to the future reputation in a depreciated way. Health outcome actually is two-dimensioned plane, which increase with the effort argument, increase with actual medical services to some optimal point, and then decreases.

Effort e belongs to $[\underline{e}, \overline{e}]$, meaning that there is minimum amount of effort required by the physician because of his professional norm. Without loss of generality, I assume $e \in [0, 1]$. [5]

3.3 Utility

Put all things together, physician's utility is a function of the income, reputation, patient's health, the level of inducement, and the effort. To include patient's health h_t into the utility function to stands for the altruism of the physician. Patients' health is one of the physicians' consideration.

We assume that u is twice differentiable and $u_y > 0$, $u_{yy} < 0$, $u_h > 0$, $u_{hh} < 0$, $u_R > 0$, $u_{RR} < 0$, $u_e < 0$, $u_{ee} < 0$, $u_i < 0$, and $u_{ii} < 0$.

[5] Physicians may employ costly precautionary treatment in order to avoid nonfinanical penalties. Kesseler and McClellan (1996) give very detailed discussion. In this study, we examine the identical physicians and the $\underline{e}$ makes sure that physicians behave legally.

4 Static Model

4.1 Static Model for FFS

A physician controls the inducement i and effort e to maximize

$$u(y, h, R_0, i, e) + qR_1 \tag{5}$$

where $y = n(R_0)(P - C)(x^* + i)$, $R_1 = \rho R_0 + (h(h_0, x^* + i, e) - h_0)$.

To do the foc, we have:

$$u_y n(P - C) + u_h h_x + u_i + q h_x = 0 \tag{6}$$

$$u_h h_e + u_e + q h_e = 0 \tag{7}$$

We can use the usual marginal benefit and marginal cost to explain the foc. The marginal cost of effort equals to the marginal benefit of effort, which is composed of two parts. First, the addition effort will increase patient's health, which gives physician utility from the health. Second, the effort increasing physician's future reputation. To put additional unit of inducement, physician's income will increase, but the inducement lower the patient health, give physician psycho cost, and also may affect the future reputation through the patient health outcome. In Equation 6, only when i equals 0, the h_x, which equals h^*_x, will be zero. Recall that h(x) increase with some x until x^*, and then decrease because of too much unnecessary medical services. When i is not zero, the u_i is always negative.

We can find in the Equation 6, there is always inducement. If the utility from the extra income is higher that the disutility from i, there will be inducement that more than the optimal level.

Proposition 1: Under fee-for-service system, inducement always happen on the decreasing part of the health function.

Proof: If it is on the increasing part, there always exist lower inducement level that can increase the income, increase patient health and reduce disutility from inducement.

4.2 Static Model for Capitation

The model is almost as same as before except the income equation is different. A physician controls the inducement i and effort e to maximize

$$u(y, h, R_0, i, e) + qR_1 \tag{8}$$

where $y = n(R_0)(r - C(x^* + i))$, $R_1 = \rho R_0 + (h(h_0, x^* + i, e) - h_0)$.

To do the foc, we have:

$$-Cu_y n + u_h h_x + u_i + qh_x = 0 \tag{9}$$

$$u_h h_e + u_e + qh_e = 0 \tag{10}$$

We find that there will be inducement in this payment system also. However, the inducement is negative, meaning the physician is giving less medical services than the optimal. This result is consistent with the literature. Since the effort will not influence the income in the static model, the foc for effort is as same as before.

Under FFS, physician always induce more than the optimal, however, under managed care, physician always inducement less than the optimal.

4.3 Comparative Analysis

Do the total differential for the FFS static model, where h_x is always negative. I get the following solution[6]:

[6] Proof will be included in the Appendix

Proposition 1: If the Arrow Pratt relative risk averse ratio is less than 1, $\frac{di}{dP} < 0$; If Arrow Pratt relative risk averse ratio is larger than 1, $\frac{di}{dP} > 0$.

Proposition 2: If the Arrow Pratt relative risk averse ratio is less than 1, $\frac{de}{dP} > 0$; If Arrow Pratt relative risk averse ratio is larger than 1, $\frac{de}{dP} < 0$.

These conclusions are consistent with the literature. When the physician is income risk averse, he would like to induce more and reduce the effort level.

We can do the total differential for the Capitation static model and follow the same procedure. We need more assumption to draw some conclusions.

With the reputation consideration, the physician will give less inducement, which will affect the future income and reputation. Physician will also input more effort if he is considering the reputation. Nonetheless, in the static model, we can not tell the effort effect on the reputation building and thus the effect on the future income. Let's try to expand the model to two periods.

5 Two Period Model

Write out the two periods utility function:

$$u(y_0, h_1, R_0, i_1, e_1) + \beta(u(y_1, h_2, R_1, i_2, e_2) + qR_2) \tag{11}$$

where

$$
\begin{aligned}
y_0 &= n(R_0)(P-C)(x_1^* + i_1) \\
y_1 &= n(R_1)(P-C)(x_2^* + i_2) \\
R_1 &= \rho R_0 + h_1(h_{10}, x^* + i_1, e_1) - h_{01} \\
R_2 &= \rho R_1 + h_2(h_{02}, x_2^* + i_2, e_2) - h_{02} \\
&= \rho^2 R_0 + \rho(h_1(h_{10}, x^* + i_1, e_1) - h_{01}) + h_2(h_{02}, x_2^* + i_2, e_2) - h_{02} \\
& \quad h_{01}, h_{02}, x_1^*, x_2^*, R_0 \ \textit{is given.}
\end{aligned}
$$

I am trying to solve for $i_1^*, i_2^*, e_1^*, e_2^*$. We can solve it recursively, I think.

6 Future Study

There are some facts that I will solve in this paper. I have mentioned some already. First, there maybe uncertainty in the health outcome, and patient may not perfect predict the physician's effort. Second, the physician's heterogeneity in the ability. Also, I did not assume the switching cost. In fact, the switching cost might be very high for a patient to change a doctor.

Further, I can consider the group reputation of the medical practices. Large amount physicians are engaged in group medical practices, therefore the group reputation will be useful to see the collusion within these practices. This is not within the reach of this study.

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