REPUTATION VERSUS SUPPLIER-INDUCED DEMAND IN THE MARKET OF MEDICAL CARE: AN APPLICATION OF OPTIMAL CONTROL MODEL

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ABSTRACT

This paper employs a dynamic optimal control model which is consistent in the explanation of optimal treatment (output) decision of the supplier and how the patients translate signal of advertising-like and reputation into expectation of quality and price. The supplier's advertising-like efforts in relation to the size of the service facility signal the level of price rather than quality. Since the paper also aims to provide an alternative mechanism and measurement of the potential induced demand in medical care market equilibrium, a good quality-price-ratio may be perceived as non-exit induced demand whereas a low quality-price-ratio is seen as an exit induced demand. Whereas the paper considers quality to be a given constant (although known only by the physician and probably by old patients), the price also reflect the quality-price-ratio. Price cuts lead to a preferable while an increase in price result in a worse quality-price-ratio and decreasing reputation. An interesting focus is, therefore, on the price (fee) policy and the advertising-like expenditure of a medical care provider. Advertising-like reflects the medical care provider's investment while reputation results from the number of treated patient and the patient's experience. Reputation increases according to the service of the provider and the degree of the patient's satisfaction with the realized quality in relation to the price charged. Reputation is thus under the medical care provider's controls, but the question is whether and how the physician should invest in this kind of abstract asset. The dynamic modelling of reputation and the analysis, however, show that there are two optimal output policies of the medical care provider, both being departure from the price-corresponds-to-quality mode. One policy is the unexpected cheap service. On the others hand, the supplier might also work in an optimal way by charging too much with respect to the offered quality such that patients have every reason to halt further visits, this way reducing but not eliminating future demand. Whichever of the two departures is the case, a relatively high or a relatively low quality is signaled by reputation.

INTRODUCTION

The study of health economics has traditionally focused on "special characteristics" of medical care market equilibrium (Kessel, 1958; Arrow, 1963; Pauly, 1980; Yunus, 1994). The problem is the difficulty of evaluating medical services. It is asserted that demand is physician-controlled

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from the observation that physician density and both physician fees and services are positively associated (Evans, 1974; Fuchs, 1978). Other studies construct models by using other criteria such as medical knowledge differential (Bunker and Brown, 1974; Hay and Leahy, 1982). The asymmetric information about the potential for supplier-induced demand is limited in the current literature to arguments about medical ethics and target income arguments. Still, there are no grounds to believe that providers are not willing to engage in opportunistic behavior (Coyte, 1985; Reinhardt, 1985, Yunus, 1990).

This paper provides an alternative mechanism and measurement of the potential induced demand in medical care market equilibrium. The analysis provides a departure from the piecemeal approach of the existing asymmetry information literature. Chan and Leland (1982) considered equilibrium price and quality combination in markets with imperfect information about price, quality or both. Salop and Stiglitz (1977) analyzed information externalities in a mixed equilibrium: uniformed consumers benefit from the presence of informed consumers. The paper adopts the model of Spremanns (1985) which is consistent in the explanation of optimal output (treatment) decision of the supplier and how the patients translate signal of advertising-like and reputation into expectation of quality and price.

The focus is on the price (fee) policy and the advertising-like expenditure of a medical care provider faced with patients who are only incompletely informed about both quality and price. Quality and price might not be directly observed before a patient's visit to the supplier or provider (an individual physician or medical unit and hospital). A good quality-price-ratio may be perceived as non-exit induced demand whereas a low quality (in relation to the price charge) is seen as an exit induced demand.

The information that the patient utilizes is based on advertising-like and reputation. Advertising-like reflects the medical care provider's investment while reputation results from service (sales or the number of treated patients) and the patient's experience. Advertising-like expenditure can be inferred from outward appearance, building and location; reputation from word-of-mouth. In a situation where interested patients communicate with others who have had experience of the service, each patient treated or each unit of the service sold carries a market signal. The intensity of this signal increases with: 1) the total number of patient already treated (the total quantity already sold), and 2) the quality-price-ratio as perceived by the old patients. In this sense, reputation is an abstract asset, which increases according to the service of the provider and the degree of the patient's satisfaction with the realized quality in relation to the price charged. Reputation is thus under the medical care provider's controls, but the question is whether and how the physician should invest in this kind of abstract asset.

Whereas the paper considers quality to be a given constant (although known only by the physician and probably by old patients), the price also reflect the quality-price-ratio. Price cuts lead to a preferable while an increase in price result in a worse quality-price-ratio and decreasing reputation.

The dynamic modelling of reputation and the analysis show that there are two optimal output policies of the medical care provider, both being departure from the price-corresponds-to-quality mode. One policy is the unexpected cheap service. On the others hand, the supplier might also work in an optimal way by charging too much with respect to the offered quality such that patients have every reason to halt further visits, this way reducing but not eliminating future demand. The supplier's advertising-like efforts in relation to the size of the service facility signal the level of price rather than quality. Whichever of the two departures is the case, a relatively high or a relatively low quality is signaled by reputation.

THE MODEL

The service is provided at continuous time t and the total spot demand q_t is assumed to depend on: 1) the current reputation R_t (new patients), 2) the price p_t (old patients), and 3) the stock A_t of cumulative advertising-like expenditure (old and new patients). Simplifying the demand function with respect to p_t and A_t by supposing constant elasticity, $\eta > 1$ with respect to price, and $\omega \ \varepsilon$ [0,1] with respect to the stock of cumulative advertising-like expenditure. This means

$$(1) \qquad q_t = p_t^{-\eta} A_t^{\omega} f(R_t)$$

where the positive function f transfers reputation R_t into sales (number of treated patients) level. Advertising-like as a form investment is

$$(2) \qquad \dot{A}_t = a_t - \delta A_t$$

where the stock $A_t \geq 0$ and $\delta > 0$. Since reputation is understood as information related to former visits to the service location, the time derivation R_t is assumed to be proportional to the quantity q_t of additional word-of-mouth carriers. Further, the qualitative content as well as the intensity of the message carried by sold units will depend on the quality-price-ratio. This is the ratio p^0/p_t, where p_t is the price actually charges and where p^0 to be determined later, denotes a hypothetical price that "corresponds" to the given quality. Thus, the differential equation (3) $\dot{R}_t = h(p^0/p_t)\, q_t - \tau R_t$

where h is the experience function which describes the effect of quality-price-ratio, p^0/p_t, upon the patient's judgements.

The experience function h in (3) will clearly be monotonic. We choose the scale in which reputation is measured such that $h(p^0/p_t) > 0$ for services of good value, i.e. $p^0 > p_t$, and $h(p^0/p_t) < 0$ for services that are too expensive, i.e., $p^0 < p_t$. Consequently, $R_t > 0$, means that word-of-mouth promotes demand. In the case of $R_t < 0$, what people say works against the physician's services. It is possible to think of $h(1) = 0$ and $R_t = 0$ as neutral levels. The function f in (1) has positive values and increases for all relevant levels of reputation.

The basic problem of the medical care provider can thus be stated: at instant s, find a price policy p_t and an advertising-like expenditure at, $s < t < \infty$, that maximize the present value of net income

$$(4) \quad \pi_s = \max \int_s^{\infty} [(p_t - c)\, q_t - a_t]\; e^{r(s-t)}\, dt$$

subject to (1), (2), and (3). The rate of interest is $r > 0$ while $c > 0$ denote marginal cost.

The solution to the problem in (4) will be found by simplifying restrictions on h in (3) where P1, P2, P3 are the sub-problems, thus,

P1 : $h(p^0/p_t) \equiv 0$, no formulation of reputation at all.

P2 : $h(p^0/p_t) \equiv \alpha$, reputation reflects only the frequency of visits to the service location.

P3 : h is switching,
$h(p^0/p_t) \equiv 1$ if $p^0 \geq p_t$ (good value, non-exit induced demand)
$h(p^0/p_t) \equiv -1$ if $p^0 < p_t$ (worse quality-price-ratio, exit induced demand).

THE VALUE OF REPUTATION

The solution to problem P1, where service decisions of the provider have no effects on reputation or future demand, is that optimal pricing must consequently satisfy the marginal revenue equals marginal cost (MR=MC) rule at all points of time, $p_t(1-1/\eta) = c$, or equivalently, $(p_t - c)/p_t = 1/\eta$. Hence, the optimal price is constant,

(5) $p_t = p^0 = (\eta/\eta - 1)\, c$,

and this defines the price level p^0.

The optimal size of the stock A_t of cumulative advertising-like expenditure can be found as follows

(6) $(p_t - c)\ \partial q_t / \partial A_t = r + \delta$

DEFINITION 1: *The holding cost of stock A_t in relation to output q_t is called relative advertising-like effort e^t, $e^t = (r + \delta)\, A_t / q_t$.* Condition (6) says that the relative advertising-like efforts will be chosen by the supplier to be proportional to the margin,

(7) $e^t = e^0 = \omega\, (p^0 - c) = \omega\, c/\eta - 1$

with promotional elasticity ω as factor. Both optimality condition (5) and (7) provide reference levels for the price and the relative advertising-like effort. These reference levels will be of use in the other sub-problem P2 and P3, where reputation in (1) and (3) is endogenous.

In order to evaluate the feedback of former output decisions on current demand via the means of reputation, we have to determine the marginal value of reputation in term of the criterion (4), that is,

(8) $v_s = \partial\pi_s / \partial R_s$.

Clearly, $v_s > 0$ at all points of time, because additional reputation promotes demand ($f' > 0$) and thus net income, too.

With definition (8) the margin $p_t - c$ can now be corrected. Writing the full differential $\partial\pi_t/\partial q_t = \partial\, [(p_t - c)\, q_t - a_t]/\partial q_t + (\partial\pi_t/\partial R_t)\ (\partial R_t/\partial q_t)$, we get

(9) $\partial\pi_t / \partial q_t = p_t - c + h\,(p^0/p_t)\, v_t$

for the marginal gain in terms of π due to one additional service unit brought into the market at time t. The margin is no longer the mere difference of price and marginal cost because of the additional terms $h(p^0/p_t)v_t$ which easily can be identified as information value (in terms of π) of the signal carried by one additional service unit into the market. Clearly, it is the sign of the experience $h(p^0/p_t)$, i.e., the qualitative judgement the individuals make upon the service, which determines whether the information value $h(p^0/p_t)\, v_t$ is positive or negative.

Marginal value of reputation is the current value adjoint of the state variable R in the problem (1), (3), (4) of optimal control. The maximum principle yields the Hamiltonian

(10) $H = (p_t - c)\, q_t - a_t + v_t\, (h\,(p^0/p_t)\, q_t - \tau R_t)$

and the adjoint differential equation

(11) $\dot{v}_t = -\,[h(p^0/p_t)\ \partial q_t / \partial R_t - r - \tau\,]\, v_t - (p_t - c)\ \partial q_t/\partial R_t$

where no transversality condition is required because of the infinite time horizon. To give an economic interpretation note that the adjoint equation (11), in view of (9), can also be written in the form

(12) $\dot{v}_t + (\partial\pi_t/\partial q_t)(\partial q_t/\partial R_t) = (r + \tau)\, v_t$.

This is the equilibrium relation for investment in reputation.

A long run equilibrium requires that both the state variable ($\dot{R}_t \equiv 0$) and its dual ($\dot{v}_t \equiv 0$) be stationary, yielding the system

(13) $v_\infty = \partial\pi_\infty / \partial q_\infty \,.\, \partial q_\infty / \partial R_\infty \,.\, 1/(r + \tau)$

and

(14) $R_\infty = h\,(p^0/p_\infty)\, q_\infty / \tau$

where stationary values are indicated through the infinity symbol ∞. Equation (13) confirms that the value of one more unit of reputation is equal to the capitalized stream of derivable income, given through the product of the full margin (9) and effect $\partial q/\partial R$ that reputation has on demand. The discount factor $1/(r + \tau)$ thereby includes interest as well as depreciation of reputation. The resulting long run stationary equilibria (13) and (14) depend on the supposed experience function h.

DEPARTURE FROM NON-EXIT INDUCED DEMAND PRICING

Having determined the value of reputation, we can solve the problems P2 and P3 where the feedback of output decisions on current demand is essential. The sub-problem P2 concerns the effects of a signal that is spread proportionally to output quantity (the number of treated patient). The judgements of patients (customers) are still exogenously given, $h(p^0/p_t) \equiv \alpha$, independent of the realized quantity-price-ratio. The way reputation is accumulated through output

(15) $\dot{R}_t = \alpha q_t - \tau R_t$,

and its effects on future demand, may thus be seen as an intertemporal externality of demand.

Some conjectures about comparative results are suggested in the case $h(p^0/p_t) \equiv \alpha$. Consider first the case of positive externality $\alpha > 0$. It might intuitively be expected that such a situation, where each patient treated (unit sold) carries as a positive message into the market, leads to a sure reduction of the optimal relative advertising-like effort and that demand, stabilized through word-of-mouth, allows for a certain increase in price and in that way the qualitative judgement $h(p^0/p_t) \equiv \alpha > 0$ is not altered. On the other hand, it seems that negative externalities, $\alpha < 0$, cause the need for compensation through an increase of the relative advertising-like effort and that price cuts might be advisable, as considered in the reference levels (5) and (7) which are optimal for $\alpha = 0$. Hence, the conjuncture is that $e < e^0$ and $p > p^0$ are optimal if $\alpha > 0$; further that $e > e^0$ and $p < p^0$ are optimal if $\alpha < 0$.

These first two results, however, indicate that these conjectures are not quite true. The first theorem considers the optimal correction of the relative advertising-like effort under the condition that the hospital (other medical care provider) does not depart from the classical pricing rule (5), which refers to the non-exit induced demand pricing.

THEOREM 1: *Let the relative advertising-like effort* $e^\#$ *be a solution of P2 subject to the condition that price policy* p^0 *is still applied. Then* $e^\#$ *and* e^0*, see (7), are related according to*

(16) $e^\# = e^0 + \omega\alpha\, v_t$

which means $e^\# > e^0$ *in the case of positive externalities and* $\alpha > 0$*, and* $e^\# < e^0$ *if* $\alpha < 0$ *for all time t.*

Proof: Maximization of the Hamiltonian (10) with respect to A_t and under condition $h(p^0/p_t) \equiv \alpha$ and $p_t \equiv p^0$ results in $(p^0 - c + \alpha v_t)(q_t/A_t) = r + \delta$. This by, definition 1, leads to $e^\#_t = \omega(p^0 - c + \alpha v_t)$ which is (16). The inequalities between $e^\#$ and e^0 result from the positivity of the marginal value of reputation, $v_t > 0$. Q.E.D.

THEOREM 2: *Let p* solve P2 whereby the advertising-like policy may either be optimal, too, or given beforehand some other way. Then at all points of time, marginal income* $p^*_t\ (1 - 1/\eta)$ *equals full marginal cost (marginal cost c corrected by the information value* αv_t*), that is*

(17) $p^*_t\ (1 - 1/\eta) = c - \alpha v_t$,

or equivalently,

$$(18) \quad p^*_t = p^* - (\eta / 1 - \eta)\, \alpha v_t .$$

Consequently, the optimal quality-price-ratio will be preferable ($p^*_t < p^0$) if positive reputation is generated, $\alpha > 0$. Whereas a worse quality-price-ratio is optimal for the supplier in case $\alpha < 0$.

Proof: Maximizing the Hamiltonian (10) with respect to the price results in (17) from which (18) and the statements on the quality-price-ratio follow because of (5) and $v_t > 0$. Q.E.D.

DEFINITION 2: *The price p_t charged at the moment to patients who are leaving the doctors' service units is called exit induced demand if $p_t > p^0$, and it is termed non-exit induced demand if $p_t < p^0$.*

Exit induced demand corresponds to a worse quality-price-ratio while non-exit induced demand refers to preferable quality-price-ratio. In this terminology, Theorem 2 provides an alternative explanation of limiting induced demand in relation to the target income argued by Evans (1974) and also the medical ethics argument, in which a physician who maximizes his income with respect to price will apply induced demand if negative rumors are spread about his treatment. He will offer non-exit induced demand, if treated patients speak in favor of his medical clinic. Essential to note is the if-then-direction in these statements.

These results are in contrast to previous conjectures about advertising-like and price. It turns out, however, that the comparison made in Theorem 1 crucially depends on the application of price p^0 instead of p^*. The relation between $e^\#$ and e^0 converts into its contrary if optimal pricing is applied.

THEOREM 3 : *If e^*, p^* simultaneously solve P2, then the proportionality*

$$(19) \quad e^*_t = \theta\, p^*_t$$

holds for all time t, where

$$(20) \quad \theta = \omega / \eta = - \partial p_t / \partial A_t \,.\, A_t / p_t$$

denotes the promotional price elasticity. In particular, the relative advertising-like effort is reduced with respect to the reference level in the case of positive externalities, $e^*_t < e^0$ if $\alpha > 0$. On the other hand , $e^*_t > e^0$ hold if $\alpha < 0$.

Proof: Derive $e^*_t = \omega(p^* - c + \alpha v_t)$ as in the demonstration of (16). With (17) follows statement (19). The relation between p^* and p^0 made in Theorem 2 can thus be transferred into the stated inequality between e^* and e^0.Q.E.D.

This result illuminates the allocational implications reputation has if generated according to (15). In a situation where positive market signals are spread as output increases ($\alpha > 0$), the medical provider unit reallocates the promotional effort from the public-like advertisement in favor of price cuts, thus increasing sales and utilizing reputation as a new information channel. But if, word-of-mouth is counter productive ($\alpha < 0$), the spread of the signals must be reduced in favor of advertising-like, where the tenor of the message is under the provider's control.

Advertising-like effort e may means a show in relation to the size of medical clinic or hospital. Knowing that (19) is the optimal for the medical unit, a new patient may infer the level of the price that will be charged. Quality of service, however, can not be deduced from e alone. Instead, reputation may be used as a second source of information. If word-of-mouth works against the provider, exit induced demand is optimal for the hospital: equivalently, quality is low with respect to levels (19) of relative advertising-like effort and price. In a situation of positive reputation, on other hand, non-exit induced demand is optimal for the hospital. As a consequence (not as cause) there is a good quality-price-ratio. So the advice is: location, medical protocol, and uniformed medical attendants indicate the amount on the bill the patient will finally pay in a medical unit or hospital. Departures from classical pricing, that are what the quality-price-ratio is, can be inferred from reputation.

A SELF-FULFILLING PROPHECY

From problem P2 and P3 where the judgement becomes endogenous: if the quality-price-ratio is good ($p_t \leq p^0$) than customer contributes to positive reputation (h=1), but in the case of a high price with respect to quality ($p_t > p^0$) customers (the former loyal patients) react by the accumulation of negative reputation (h = -1). This behavior of patients closes the loop such that, like a self-fulfilling prophecy, exactly two modes can occur in the physician's decision-making and the patients' judgement, both being considerable departures from the price corresponds-to-quality mode. Either the medical provider is cheap (for the quality offered), resulting in the generation of positive reputation which, again, makes price cuts optimal. Or the server is expensive (with respect to quality), leading to the accumulation of negative reputation which, in turn, makes high pricing optimal.

THEOREM 4: *If the price policy p^* solves problems P3, then: either p^* is non-exit induced demand,*

$$(21)\quad p^0 - p_t^* = (\eta/1-\eta)\, v_t$$

and positive reputation is generated. Or p^* is exit induced demand,

$$(22)\quad p_t^* - p^0 = (\eta/1-\eta)\, v_t$$

and the negative reputation is generated. Here, $v_t > 0$ denotes the respective values of marginal reputation, see (12). In both cases, an optimal relative advertising-like effort e^* is proportional to the price charged according to (19).

Both policies (21) and (22) are stable in the sense that variations in them do not lead to increase in the criterion (4) as long as the respective variations are small enough to cause a switching in the patient's judgement. Which of the two globally optimal policies will crucially depend on the effect that reputation has on demand. Real life experience tells that both types of optimal policies occur. Since organizational of medical care services require standardization of skills or output (treatment); referral, or the mere scale and scope of the hospital business will improve the importance of positive reputation as an indicator for and as a result of a good quality-price-ratio. Nevertheless, the small and specialist physician who provides treatment that is infrequently consumed and produced, may find induced demand in the sense of high price charged in spite of the negative reputation created. Quality may be high, of course, but prices are terrific.

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