UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Scienze Economiche "Marco Fanno"

INVESTMENT IN HOSPITAL CARE TECHNOLOGY UNDER DIFFERENT PURCHASING RULE: A REAL OPTION APPROACH

ROSSELLA LEVAGGI
Università di Brescia

MICHELE MORETTO
Università di Padova

September 2007

"MARCO FANNO" WORKING PAPER N.46

Investment in hospital care technology under different purchasing rules: a real option approach

Rosella Levaggi* and Michele Moretto†

Final version September 2007

Abstract

Quality of health care is the product of several factors as the literature has long recognized. In this article we focus on the relationship between quality and investment in health technology by analysing the optimal investment decision in a new health care technology of a representative hospital that maximises its surplus in an uncertain environment. The new technology allows the hospital to increase the quality level of the care provided, but the investment is irreversible. The article uses the framework of the real option literature to show how the purchaser might influence the quality level by setting a quality-contingent long-term contract with the hospital.The investment in new technology is in fact best incentivated within a long-term contract where the number of treatments reimbursed depends on the level of investment made when the technology is new. In this way, asymmetry of information

*Dipartimento di Scienze Economiche, University of Brescia, Via S. Faustino, 74b, 25122 Brescia (Italy) E-mail: levaggi@eco.unibs.it.

†Dipartimento di Scienze Economiche, Università di Padova, via del Santo 33, 35100 Padova (Italy), E-mail: michele.moretto@unipd.it

does not affect the outcome of the contract. In our model in fact the purchaser can verify the level of the investment only at the end of each period but the purchasing rule has an anticipating effect on the decision to invest. **JEL Classification: I11,D81 Key Words: Health care technologies, Medical quality, Irreversible investments, Real options.**

1 Introduction

The design of contracts for health care is not straightforward due to the peculiar characteristics of the product sold on this market which are well known and will not be recalled here. The literature has long pointed out the existence of a trade-off between the cost of the service, its quality, the ownership of the hospital and the level of enforcement of the contract (Chalkley and Malcomson, 1998, 2000 and 2002; Levaggi 2005 and 2007) and several models have been developed to show the effects on the contract of uncertainty, asymmetry of information and competition (Levaggi, 1996 and 2005, Chalkley and Malcomson, 1998 and 2000, Ma, 1994, Ellis, 1997, Entoven, 2002, Kessler and McClellan, 2000, Gaynor and Vogt, 2003, Biglaiser and Ma, 2003). In health care, quality is defined as a multivariable vector that includes all the aspects of medical care (such as its appropriateness, the investment in technology), other aspects that are not strictly medical, but that can improve hospital stay[1] and some characteristics of the patient that are non-observable. For this reason, even when quality is observable, it is non-contractible because the clause would not be enforceable.[2] The common feature of these models is that the quality is not verifiable and it is determined by running costs. However, the most recent literature points out that technological changes produce substantial improvement in prognosis for several ailments (Baker and Phibbs, 2002a,b; Medtap, 2004, Bokhari, 2001; HTC 2003), i.e. quality of health care is strictly related to the level of investment in new technology. In this light, treating quality as a run-

[1] These are services such as the number of beds per room, visiting hours, private telephones, nurses per ward, etc.

[2] For the definition of observable but non-verifiable variables in contract theory see e.g. Laffont and Martimort (2002).

ning cost is no longer satisfactory. For this reason, in our model we assume that medical care is the main determinant of quality which is in turn the result of an investment decision in health care technology. Once the hospital has made a specific quality-improving investment, the decision is irreversible and the investment determines the quality level of the care produced by that provider for the years to come. The investment in medical quality considered in this paper is an impure public good. When the technology is innovative, it requires higher operating set-up costs, but it produces a positive externality on the rest of the scientific community because the followers in introducing the technology will face lower costs since they can acquire the learning process of the leader at no cost; in this respect the investment in medical quality is a privately provided public good (Bergstrom et al., 1986). These assumptions shift the focus of the incentive-compatible contract from cost revelation to intertemporal investment decisions. The aim of this paper is in fact to deal with those non-market strategies the purchaser can implement to enhance quality in a setting where this variable depends on an irreversible investment which produces a positive externality. We carry out the analysis using the method proposed by the real option literature which, starting from the seminal works by Brennan and Schwartz (1985) and McDonald and Siegel (1986), has highlighted the analogy between security options and the opportunities to invest in real assets.[3] This literature stresses the fact that when costs are sunk and there is uncertainty over future rewards, the timing of the investment decision is crucial. In particular it shows that irreversibility and uncertainty induce the firm to optimally invest only when the value of the investment exceeds the value of the option of waiting before making

[3] An excellent survey of the main theory is given in Dixit and Pindyck (1994) and Trigeorgis (1996), see also Dixit (1992) and Pindyck (1988).

the irreversible decision.[4] This approach allows us to introduce modularity which is peculiar to much investment in hospital care.[5] To date, there have been only a few attempts to model health care from a real option perspective. Exceptions are represented by Palmer and Smith (2000), Driffield and Smith (2006). Palmer and Smith (2000) seek to model the adoption of a new technology as an options problem while Driffield and Smith (2006) aim at assessing the methodological and practical implications of applying real options analysis to a clinical decision-making problem in which deferral is considered a relevant alternative. Bös and De Fraja (2000) share some of our assumptions since quality is assumed to be the result of an investment decision and it is irreversible. In the above paper, however, the intertemporal setting is not developed as the authors concentrate their analysis on the effects of non-contractibility of quality[6] and the hospital that first innovates does not produce any positive externality on the followers. On a formal level we develop a two-period partial equilibrium model à la Abel et al. (1996) where the hospital is allowed to expand its capacity by making an investment in health care technology now or in the future. In this environment we study the relationship between investment in quality when it is innovative (i.e. the first period) and a long-term contract with the hospital. The main findings of our paper can be summarised as follows:

[4] This is indeed an application of the "bad news principle of irreversible investment" (Bernanke, 1983).

[5] As an example we can consider a PET scan. The hospital can decide to buy a mobile appliance whose cost can be shared among several hospitals, it can decide to build its own PET centre and it can finally decide to produce its own radio drug.

[6] Bös and De Fraja (2000) show that the hold-up problem that emerges in this case may be alleviated if the health authority arranges to purchase the service from providers other than the hospital.

a) Hospitals make substantial investment in the first period (i.e. when technology is new) only if they are offered long-term contracts (a two-period contract in our model); if this is not the case, the investment in quality at $t = 1$ will be minimum and its intertemporal allocation will mean that hospitals invest in a technology only when it is a mature, well-established technique. This result is in line with the recent literature suggesting that the use of long-term contracts reduces the hold-up problem (Chalkley and Malcomson, 2000; Chung, 1991; Aghion et al.,1994).

b) If the purchaser has the power to send patients to a specific provider, quality at $t = 1$ is maximised if the purchaser makes the number of patients treated in the second period depend only on the investment made in period one. The reason is simple: by tying the hospital's future rewards to the investment made today it cancels out its option value to delay the investment decision. This result, which derives from the properties of the option models, has important policy implications as the investment in quality can usually be observed (hence verified) only ex post.[7]

c) Finally, the adoption of the technology at $t = 1$ implies a higher cost for patients treated so that the purchaser faces a trade-off between quality, technological content of the care provided and average cost of provision.

[7] The introduction of protocols, like the guidelines issued by NICE and NCQA, for the treatment of specific ailments allows ex post verification of the appropriateness of the care offered.

The paper will be organised as follows: in the next section the features of the model are presented, in section 3 the hospital's investment decision is presented, in section 4 we show how quality decisions at time 1 vary with the purchasing rule and, lastly, section 5 concludes the paper.

2 The model

The model deals with the investment choices of a representative hospital in a two-period framework as a proxy for long-term contracts. To simplify the analysis, we assume that patients can be affected only by one disease that requires a standard treatment. The production process is uncertain, however, due to productivity shocks deriving from personal characteristics of the patient or from input prices. Health care is an input into a process that leads to recovery. The personal ability of each individual to take advantage of the treatment determines the quantity of resources to be used. The price of the treatment might also vary because of a change in the input prices, in the protocols or the guidelines set up for the treatment of a particular ailment. In this paper we do not make any specific assumption about the organisation of health care so that the purchaser might alternatively be a profit maximising insurance company, an HMO or a benevolent health authority that wishes to maximise patient welfare through the supply of hospital care and the provider might be a private individual, a profit-making institution or a public hospital.

2.1 Quality

The traditional literature dealing with contracts for hospital health care assumes that quality is a variable cost which might be observable ex post, but often it is not contractible.[8] We argue that this way of modelling quality might not reflect its actual nature. Quality is a multidimensional vector that includes hotel and medical services. The first category defines activities that are not strictly medical, but that can improve hospital stay. Medical activities improve the prognosis and the recovery process of each admission. They include the technology used to treat the patient, the appropriateness of the treatment offered and the motivation/effort of the medical staff in taking care of the patient. Hotel-related quality can be modelled as a variable cost, but the medical dimension derives mainly from an investment decision. Both elements are extremely relevant in determining the patient's utility, but in this paper we restrict our definition of quality to medical quality and we argue that this specific component depends on the investment in health technology made by the provider.[9] The investment is specific, irreversible, can be sequential and determines the type of treatment that can be supplied to the patient. It follows that the decision of the hospital concerning the level of quality to supply becomes an intertemporal decision and the type of contract set by the purchaser is the main variable that determines the quality level of the care to be provided. The assumption that medical quality depends on an investment decision has several effects on the way of approaching the problem:

- contracts for health care should have an intertemporal dimension;
- the trade-off between the investment in quality, contract duration and purchasing rule has to be made explicit;

[8] See Chalkley and Malcomson (1998, 2000).

[9] In other words we assume that the treatment offered to the patient is always appropriate given the technology in the hospital.

- the intertemporal dimension of the contract makes the medical quality verifiable ex post.

2.2 The purchaser

The purchaser can influence the quality of the treatment offered by setting appropriate contract rules. Chalkley and Malcomson (1998; 2000) show that to pursue the maximisation of quality a simple price-quantity schedule is not sufficient since it might lead to treating patients with a low benefit or to delivering too low a quality level. They suggest the use of more sophisticated contracts which in a static framework leads to a payment schedule that depends on the number of patients treated and on those demanding health care. The same authors show that in an intertemporal framework, hold-up and ratchet effects can seriously affect the level of quality. Our paper uses the suggestion of this literature to make the first step towards setting an optimal intertemporal contract. Our aim is in fact to show the effects on the provider's investment decision of alternative ways to set the purchasing rule. In our paper we assume that the purchaser rewards the hospital by setting a quality-contingent long-term contract with the hospital where a price p is set for each treatment while the number is quality dependent. The number of patients needing treatment is independent of quality, but the purchaser reimburses the hospital for the treatment of a number of patients $x \geq 0$ which is fixed in the first period and may increase in the second one if the hospital expands its investment in medical quality. In other words, we assume that the health authority is committed to linking the number of patients to be treated in the second period to the investment policy of the hospital $x_2(q_1, q_2)$. In particular, in the second period the number of patients increases according to the following linear purchasing rule:

$$x_2(q_1, q_2) \equiv x + \gamma q_1 + \alpha(q_2 - q_1) \tag{1}$$

where q_1 is the level of total quality in the first period, $q_2 - q_1$ is the increase of quality from period 1 to period 2, and γ and α represent the relative weights. In our paper we focus on four possible combinations which represent alternative strategies the purchaser can follow in incentivating the adoption of the new technology. They are:

- $\gamma - \alpha > 0$ and $\alpha > 0$: the number of patients reimbursed at $t = 2$ depends on the level of quality in both periods (we call this the general case).

- $\gamma = 0$ $\alpha > 0$: the number of patients reimbursed at $t = 2$ increases only if the level of total quality in the second period is higher than the level reached at $t = 1$.

- $\gamma > 0$ and $\alpha = 0$: the number of patients reimbursed at $t = 2$ depends only on the quality level reached at time $t = 1$.

- $\gamma = \alpha$: the number of patients reimbursed at $t = 2$ depends on the quality level at time $t = 2$.

This purchasing rule responds to the need often advocated (National Audit Office, 1995) to use more sophisticated payment rules to increase the performances of health care systems. Each hospital, by increasing quality (in both periods) can increase the number of its activity level. Therefore, equation (1) could represent the case where higher quality hospitals attract more patients who are free to choose their preferred provider (and the purchaser pays for the increased admissions to higher quality hospitals. See

Levaggi 2005, 2007 and Pertile 2007), or a situation in which the purchaser buys more treatments from higher quality hospitals on behalf of the patients it represents. The rule we suggest is used, in an implicit or explicit form, in several health care systems. For example, in the US, HMOs set the number of patients to be treated in each hospital according to quality indices; in the Italian NHS, an ASL (Azienda Sanitaria Locale: the purchaser) could remove (reduce) part of the yearly ceiling set on the number of treatments if the hospital increases the quality of treatments.[10]

2.3 The hospital

In our model we assume, like most of the literature on this subject, that the hospital is a surplus maximiser. The hospital's surplus function can be written as:

$$U^t(q_t, x_t, \beta_t) \equiv x_t p_t - C^t(x_t, q_t, \beta_t) \; t = 1, 2 \tag{2}$$

where p_t is the price set by the purchaser, $C^t(x_t, q_t, \beta_t)$ is the cost of production, q_t is the quality level and β_t represents productivity shocks. In our model the investment in the new technology determines the medical quality level so we use q for the level of investment and quality as well. The current investment in quality is private information to the hospital but the purchaser can verify it ex post.[11] Once the investment is undertaken it cannot be abandoned.[12] Quality accumulation is given by $q_2 = q_1 + i_2$, where

[10] It must be pointed out that, following rule (1), higher quality hospitals are rewarded with more admissions at a given price p; however, the results hold even if the number of admissions were set constant, while the price varies according to quality levels.

[11] i.e. the purchaser observes the hospital quality ex post and may verify it before a court (or a regional health office).

[12] Besides irreversibility, this assumption avoids the need to consider such operating options for the hospital like reducing output or even shutting down, thereby considering

q_1 is the stock of quality invested in the first period, i_2 denotes investment in period 2 and depreciation is absent. The hospital can invest in quality at unit cost r.[13] In addition to the investment cost, the hospital faces some operating costs in running the new technology. These operating costs differ from period to period due to our assumption concerning the nature of the investment decision. In the first period the investment in new technology has a multiplicative effect on the cost of producing health care. It comprises set-up costs such as learning cost and human capital formation. Because of the investment in the new technology, such costs are directly related to the size of the investment q rather than the number of patients to be treated x. In the second period, the extra investment in the same technology causes an increase in the cost due to pure reputation via the rule (1).[14] The operative costs in each period are given by:

$$C^t(x_t, q_t, \beta_t) \equiv \begin{cases} \theta(q_1)C^1(x, \beta_1) & \text{for} \quad t = 1 \\ \\ \begin{array}{lll} C^2(x_2(q_1, q_2), \beta_2) & \forall\ q_2 \geq q_1 & \text{with } q_1 > 0 \\ \text{or} & & \\ C^2(x, \beta_2) & \forall\ q_2 \geq 0 & \text{with } q_1 = 0 \end{array} & \text{for} \quad t = 2 \end{cases} \tag{3}$$

reducing variable costs. For further details see e.g. Dixit and Pindyck (1994).

[13] In section 4.2 we deal with the more general case in which the investment cost at time 2 is lower than the investment cost at time 1, i.e. $r_2 < r_1$.

[14] As an example we might think about introducing laser therapy to treat patients with specific ailments. In the first period we will have to bear the cost of the equipment and the cost related to teaching the staff how to use the new technology. In the second period the purchase of another laser to treat the same ailment simply increases the cost due to the increase in the number of cases treated.

where $\beta \in \mathbb{R}$ is a parameter capturing productivity shocks as well as the cost of production factors other than quality investment. We also add $\theta(0) = 1$, $\theta'(q_1) > 0$, $\theta''(q_1) < 0$, with the regularity conditions $\lim_{q \to 0} \theta'(q) > 0$ and $\lim_{q \to \infty} \theta'(q) = 0$. We complete the properties of the cost function by assuming that it is increasing and convex in the number of patients $C^t_{x_t}, C^t_{x_t x_t} > 0$, for $t = 1, 2$ and we make the following assumption on the costs of the hospital at $t = 2$:[15]

$$C^2_{x_2 x_2 \beta} > 0, \quad C^2_{x_2 x_2} + x_2 C^2_{x_2 x_2 x_2} < 0 \tag{4}$$

However, if $q_1 = 0$ the hospital may still invest in the new technology at time 2 but without reputation benefits, i.e. $C^2(x, \beta_2)$ for all q. The cost function (3) allows the model to take account of another important characteristic that the investment in medical quality has in health care. This is the innovative content of the treatment offered. In the first period the technology is innovative and requires higher operating set-up costs which are in part a positive externality on the rest of the scientific community. In the second period the new technology has become established and by making its investment in this period the hospital gains from the positive externality and may have lower operative costs. Without loss of generality, we assume in the paper that $C^1 = C^2 = C$.[16] The payment per treatment p_t can be either

[15] Note that an increase in q_2 determines an increase in the marginal costs $C_{x_2 x_2}$, plus the reduction in the revenue obtained from the infra-marginal patients $x_2 C_{x_2 x_2 x_2}$. The condition (4) assures that the latter outweighs the former. Such an assumption is consistent with even simple cost functions. For example let $C = (k - x)^{-\varepsilon}$ where ε and k are parameters. Then the above assumption is satisfied for a variety of parameter values including $\varepsilon = 2$ and $k/3 \leq x < k$.

[16] It is worth pointing out that the quality of results would not change if we assumed $C^1 \neq C^2$.

a DRG tariff or any other form of prospective price for a specific treatment based on marginal cost of production. Following Bös and De Fraja (2000) we set $p_t = C^t_{x_t}(x_t, q_t, \beta_t),\ t = 1, 2.$[17] The cost reimbursement scheme and equation (1) allow us to write the surplus function for the hospital as:

$$U^t(q_t, x_t, \beta_t) \equiv x_t p_t - C^t(x_t, q_t, \beta_t) = x_t C^t_{x_t}(x_t, q_t, \beta_t) - C^t(x_t, q_t, \beta_t)\ t = 1, 2 \tag{5}$$

Finally, we introduce uncertainty in the model through the productivity shock β. We assume that β_1 is known and normalised to 1 while $\beta_2 \equiv \beta$ is stochastic and its realisation is characterised by the cumulative distribution $\Phi(\beta)$ with density $\Phi'(\beta) > 0$ on $\beta \in [0, \infty)$, which is obseved by the hospital and the purchaser.[18]

3 The hospital's investment decision

We consider the hospital's decision to invest in health care technology in a two-period framework. If in period 1 the hospital makes an investment that it cannot resell in period 2 and future capital returns are uncertain, this investment decision involves the exercise of an option. Because of the uncertainty, the opportunity of waiting to learn more about the future hospital productivity level has a timing premium or holding value. The role of β deserves further explanation. The productivity shock can be observed by the hospital only at the beginning of each period and becomes public information. Given the marginal cost pricing rule we have assumed, the hospital

[17] The results do not change in their substance if the price were assumed fixed under a DRG system (Levaggi, Moretto and Rebba, 2005). For readers who are interested, the proof is available from the authors.

[18] As in Bös and De Fraja (2000), we assume that there is symmetry of information about the technology.

bears no risk on the running cost. However, since q_2 depends on β_2 also q_1 is affected by its realisation and in this respect it introduces uncertainty in our model. The timing of the model can be summarised as follows (Figure 1). At the beginning of period 1, the health authority announces x, the number of patients to be treated in the first period and the purchasing rule for the second period. The hospital, knowing β_1 and the purchasing rule, decides q_1. At the beginning of period 2, q_1 becomes verifiable, nature reveals β_2 and, conditional on q_1, the hospital chooses q_2.

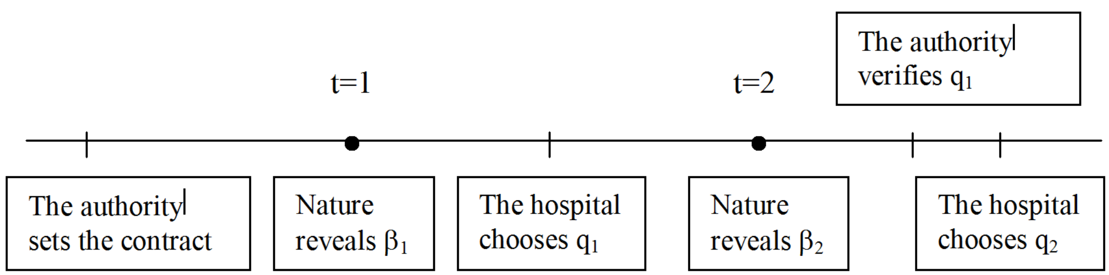

figure 1

We start by describing the hospital's action in the second period, given the stock of quality q_1 inherited from period 1. We then step back and show how the marginal profitability in the first period depends on the hospital's expected action in the second period.

3.1 Second period

The hospital's surplus at time 2 can be written as:

$$U^2(q_2, q_1, x, \beta) \equiv x_2(q_1, q_2) C_{x_2}(x_2(q_1, q_2), \beta) - C(x_2(q_1, q_2), \beta)$$

yet the assumptions on the cost function guarantee that $U^2_{q_2}(q_2, q_1, x, \beta) \geq 0$ is continuous and strictly decreasing in q and continuous and strictly increasing in β (see Appendix A). For a given stock of q_1 inherited from period 1, we can define a critical value of β:[19]

$$U^2_{q_2}(q_1, x, \beta^*) \equiv \alpha(x + \gamma q_1) C_{x_2 x_2}(x + \gamma q_1, \beta^*) = r \tag{6}$$

At the beginning of period 2, nature reveals β and the hospital will adjust its stock of medical quality to the new optimal level that we identify as $q_2(\beta)$. The stock of quality must satisfy the constraint:

$$q_2(\beta) \geq q_1 \tag{7}$$

Thus, depending on the inherited stock q_1, from (6) it emerges that when $\beta > \beta^*(q_1, \alpha)$, it is optimal for the hospital to invest in extra quality up to the point where the marginal return from quality equals the marginal investment cost (purchasing price) r. On the other hand, when $\beta < \beta^*(q_1, \alpha)$ the profitability is so low that the firm finds it convenient not to invest, so

[19] We also get:

$$\frac{\partial \beta^*}{\partial r} = \frac{1}{\alpha(x + \gamma q_1) C_{x_2 x_2 \beta}} > 0$$

and

$$\frac{\partial \beta^*}{\partial q_1} = -\frac{\alpha^2 [C_{x_2 x_2} + (x + \gamma q_1) C_{x_2 x_2 x_2}]}{\alpha(x + \gamma q_1) C_{x_2 x_2 \beta}} > 0$$

$q_2(\beta) = q_1$. Finally, by (3), if $q_1 = 0$ the surplus of the hospital at time 2 is always constant and then $q_2(\beta) = 0$ for all values of β.

3.2 First period

From (5) and (6), the following Lemma holds:

Lemma 1 *The value of the hospital's investment in medical quality, defined as the expected present value of net cash flow accruing to the hospital when the stock of quality in period 1 is q_1, is given by the following expression:*

$$\begin{aligned} V(q_1, x) \equiv\ & \theta(q_1)[xC_x(x) - C(x)] \\ & + \delta \left\{ \int_0^{\beta^*} [(x + \gamma q_1) C_{x_2}((x + \gamma q_1), \beta) - C((x + \gamma q_1), \beta)] d\Phi(\beta) \right. \\ & + \int_{\beta^*}^{+\infty} \{[(x + \gamma q_1 + \alpha(q_2(\beta) - q_1)) C_{x_2}((x + \gamma q_1 + \alpha(q_2(\beta) - q_1)), \beta) \\ & \left. - C((x + \gamma q_1 + \alpha(q_2(\beta) - q_1)), \beta)] - r[q_2(\beta) - q_1]\, \} d\Phi(\beta) \right\} \end{aligned} \tag{8}$$

where δ is the discount factor.

Proof. See Appendix A ■

Hence, the first period decision problem is simply given by:

$$q_1 = \arg\max \left[V(q_1, x) - r q_1 \right]. \tag{9}$$

The first order condition for a maximum yields:

$$V_{q_1}(q_1, x) \equiv \theta'(q_1)[xC_x(x) - C(x)] + \delta \left\{ \int_0^{\beta^*} \gamma (x + \gamma q_1) C_{x_2 x_2}((x + \gamma q_1), \beta) d\Phi(\beta) \right. \tag{10}$$

$$+\int_{\beta^*}^{+\infty}\gamma(x+\gamma q_1+\alpha(q_2(\beta)-q_1))C_{x_2x_2}((x+\gamma q_1+\alpha(q_2(\beta)-q_1)),\beta)d\Phi(\beta)\Bigg\}=r.$$

Defining q_1^{sr} the stock of medical quality that the hospital would purchase in a short-term contract (i.e. $U_{q_1}^1(q_1^{sr.},x)\equiv\theta'(q_1^{sr.})[xC_x(x)-C(x)]=r$), we can write the following proposition:

Proposition 1 *A long-term contract increases the investment in period 1:*

$$V_{q_1}(q_1,x)>U_{q_1}^1(q_1,x)\qquad\Rightarrow\qquad q_1>q_1^{sr.}$$

Proof. See Appendix B ■

This result has important policy implications: in order to increase the level of investment in new health technology, a long-term contract should be set. The reason is simple: a long-term arrangement rewards the hospital for the positive externality created by the use of the new technology at an early stage. This creates a trade-off between competition and incentives to invest in new technology. Competition is enhanced by short-run agreements that allow the purchaser to choose in each period the provider offering the lowest price. However, if quality depends on an irreversible investment decision, this policy would lead to low quality level. This might be the reason why competition in the health care market is not as high as one might expect (Eintoven, 2002; 2004). This result is in line with the recent literature that suggests that the use of long-term contracts reduces the hold-up problem (Chalkley and Malcomson, 2000; Chung, 1991; Aghion et al.,1994). Furthermore, since q_1 and hence $\beta^*(q_1,\alpha)$ are ex post verifiable, the first order condition (10) is not affected by the decision of quality at time 2. This property comes from the application of the principle of optimality of the dynamic programming. The optimality principle says that an optimal quality path has the property that, given the initial conditions and control values over an initial period, the control over the remaining periods must be optimal for the remaining problem, with the state variable resulting from the early decisions considered in the initial condition (Dixit, 1990, p. 164-166). Formally this implies finding a state contingent function $q_2(\beta)$ such that the hospital chooses the quality at time 1 by equating $V_{q_1}(q_1, x)$ to r. Suppose now that the hospital, expecting to report at $t = 2$ a higher value of investment, chooses at time 1 $\tilde{q}_2(\beta)$, with $\tilde{q}_2(\beta) > q_2(\beta)$ for all $\beta > \beta^*$. This cannot be an optimal decision. In fact, since $V_{q_1\tilde{q}_2}(q_1, x) < 0$, the hospital can do better by choosing $\tilde{q}_2(\beta) = q_2(\beta)$: the profit flow that the firm expects to obtain by following the policy $q_2(\beta)$ is the best that it can do, at least until $t = 2$.[20] Finally, since $U^1_{q_1}(q_1, x) \geq 0$ is continuous and strictly decreasing in q with $\lim_{q_1 \to \infty} U^1_{q_1}(q_1, x) = 0$, we can conclude this section by noting that $q_1^{sr.}$ is strictly positive, which also implies that:

Corollary 1 *q_1 and $q_2 \geq q_1$ are strictly positive.*

Proof. Straightforward from Proposition 1. ■

[20] Since at $t = 2$ the purchaser observes and verifies q_1 (β^*), it is always able to infer $q_2(\beta)$ directly from (10) (i.e. $q_2(\beta)$ is uniquely determined by $U^2_{q_2}(q_2(\beta), q_1, x, \beta) = r$). This makes the second period a "pure" non-verifiability model, i.e. even though the revelation of β makes q_2 common knowledge between the purchaser and the provider, it cannot be enforced by a third party. To achieve the first best allocation, a Nash implementation mechanism is needed. Laffont and Martimort (2002), for example, show that the simple incentive compatible contracts used in the adverse selection context with ex ante contracting perform quite well in the case of non-verifiability and risk neutrality of the hospital. The above, however, is beyond the scope of this paper.

4 Analysis of the results and policy implications

4.1 The trade-off between investment and purchasing rule

We begin analysing the effect of a change in the rule that links the number of patients to be treated to the investment in quality by comparing the three cases presented above. For a better understanding of the role played by the purchasing rule in the hospital's investment decision, let's use the option decomposition of (8) proposed by Abel et al. (1996). By simply manipulating (8) we are able to write:

Lemma 2 *The value of the hospital's investment can be written as:*

$$V(q_1, x) = G(q_1, x) - \delta O(q_1, x) \tag{11}$$

where:

$$G(q_1, x) \equiv \theta(q_1)[xC_x(x) - C(x)] + \delta \int_0^{+\infty} [(x+\gamma q_1)C_{x_2}((x+\gamma q_1), \beta) - C((x+\gamma q_1), \beta)] d\Phi(\beta)$$

$$O(q_1, x) \equiv$$

$$\int_{\beta^*}^{+\infty} \{ - [(x_2(q_1, q_2(\beta))C_{x_2}(x_2(q_1, q_2(\beta)), \beta) - C(x_2(q_1, q_2(\beta)), \beta)) - rq_2(\beta)]$$

$$+ [((x + \gamma q_1)C_{x_2}((x + \gamma q_1), \beta) - C((x + \gamma q_1), \beta)) - rq_1]\} \, d\Phi(\beta)$$

Proof. See Appendix C ■

The term $G(q_1, x)$ is the hospital's expected present value of returns during the contract keeping the stock of medical quality fixed at q_1. This can be interpreted as the hospital's value when it does not expand its investment in the second period. The term $O(q_1, x)$ indicates the value of the (*Call*) option to expand investment in the second period if profitability rises above

β^*. Equation (11) then has an interesting and immediate interpretation: when the hospital invests in period 1 it gets the value $G(q_1, x)$ but gives up the opportunity or option to invest in the future, valued at $O(q_1, x)$. Similarly to (10), the optimal amount of quality in period 1 depends on a comparison between marginal benefits and marginal costs:

$$G_{q_1}(q_1, x) = r + \delta O_{q_1}(q_1, x) \tag{12}$$

where:

$$G_{q_1}(q_1, x) \equiv \theta'(q_1)[xC_x(x) - C(x)] + \delta \int_0^{+\infty} \gamma(x + \gamma q_1) C_{x_2 x_2}((x + \gamma q_1), \beta) d\Phi(\beta)$$

$$O_{q_1}(q_1, x) \equiv \int_{\beta^*}^{+\infty} \frac{\gamma}{\alpha}[\alpha(x + \gamma q_1) C_{x_2 x_2}((x + \gamma q_1), \beta) - r] d\Phi(\beta) \geq 0$$

Equation (12) emphasises the role played by the option pricing approach in determining the optimal stock of investment in period 1. The hospital's optimal behaviour does not simply equalise the expected present value of marginal returns in the first period ($G_{q_1}(q_1, x)$) and the marginal cost of the investment r. Costs are represented by the purchase price of the investment, r, plus the value of the marginal call option, $O_{q_1}(q_1, x)$, as investing in period 1 gives up the opportunity of delaying the investment. There are three cases which it is instructive to examine. Defining $q_1(\gamma = \alpha)$, $q_1(\gamma = 0)$ and $q_1(\alpha = 0)$ as the stock of quality that the hospital would choose if $\gamma = \alpha$; $\gamma = 0$, $\alpha > 0$ and $\alpha = 0$, $\gamma > 0$ respectively, the following proposition holds:

Proposition 2 *The investment in period 1 can be ranked as follows:*

$$q_1(\gamma = 0) = q_1^{sr} < q_1(\gamma = \alpha) < q_1(\alpha = 0)$$

Proof. See Appendix D ■

The last proposition can be interpreted as follows: the policy of incentivating investment in technology only in the second period ($\gamma = 0$) gives the same result as a short-run contract which, being more flexible, should be preferred. A uniform incentive to investing in quality ($\gamma = \alpha$) produces a better incentive than a short-term contract, but the most effective policy is perfect discrimination ($\alpha = 0$): the last rule in fact implies that the hospital has the maximum incentive to invest in quality when the purchasing rule implies that only the investment made in the first period comes into the decision concerning the number of patients to send to a specific hospital. In other words, setting $\alpha = 0$ washes out the option value of delay held by the hospital.[21] In the latter case, in fact, the purchaser grants a sort of patent to the hospital that has first invested in the new technology. The number of patients that can be treated depends only on the level of investment made in the first period and those who invest in later periods will not see any increase in the number of cases they may treat. This result has important policy implications: even if the level of investment can be observed ex post, asymmetry of information can be ruled out of the system. When the contract is signed, the purchaser cannot observe the level of investment in health technology, but he will be able to do so before implementing the relevant part of the contract. In our model this is a sufficient deterrent to cheating on the level of investment in the first period. In the second period the issue becomes irrelevant since the new investment is not considered in the decision of how many patients to send to a specific hospital. Finally, we further investigate the effect of a change in the purchasing rule by totally

[21] It is also worth noting that the extreme result of zero investment in the second period when $\alpha = 0$ is only due to our two-period horizon setting.

differentiating the first order condition (10) with respect to α:

$$\frac{dq_1}{d\alpha} = -\frac{V_{q_1\alpha}(q_1,x)}{V_{q_1q_1}(q_1,x)} \tag{13}$$

This expression must be evaluated at the maximum of the hospital's investment choice, that is at the point at which $V_{q_1}(q_1,x) - r = 0$. Since at this point $V_{q_1q_1}(q_1,x) < 0$ by the second order condition, the sign of (13) is driven by the numerator:

$$V_{q_1\alpha}(q_1,x) \equiv \delta \int_{\beta^*}^{+\infty} \{\gamma(q_2(\beta) - q_1)\left[C_{x_2x_2} + (x + \gamma q_1 + \alpha(q_2(\beta) - q_1))C_{x_2x_2x_2}\right] +$$

$$\left.\gamma\alpha\left[C_{x_2x_2} + (x + \gamma q_1 + \alpha(q_2(\beta) - q_1))C_{x_2x_2x_2}\right]\frac{\partial q_2(\beta)}{\partial\alpha}\right\} d\Phi(\beta) < 0$$

As $\frac{\partial q_2(\beta)}{\partial\alpha}$ is generally positive, the slope of the relationships between q_1 and α turns out to be negative, i.e. $\frac{dq_1}{d\alpha} < 0$.[22] Then, by continuity, for a given value of the parameter γ, any increase in the number of patients driven by the investment in quality in the second period reduces investment in the first period over the range $(q_1(\gamma = \alpha), q_1(\alpha = 0))$.

4.2 The trade-off between quality and investment cost

So far we have assumed that $r_2 = r_1 = r$. However the cost of many health care technologies decreases as time goes by. A good example is MR scanners,

[22] To be precise, for any given $\beta > \beta^*$ the optimal investment at $t = 2$ requires:

$$U^2_{q_2}(q_2,x,\beta) \equiv \alpha x_2(q_1,q_2)C^2_{x_2x_2}(x_2(q_1,q_2),\beta) = r, \tag{14}$$

from which we can show that:

$$\frac{\partial q_2}{\partial\alpha} = -\frac{x_2(q_1,q_2)C^2_{x_2x_2} + \alpha(q_2 - q_1)[C^2_{x_2x_2} + x_2(q_1,q_2)C^2_{x_2x_2x_2}]}{U^2_{q_2q_2}(q_2,x,\beta)} \tag{15}$$

As is evident, the sign of (15) is generally positive except for value of α close to γ where it may turn negative.

the cost of which for a fixed technological level still decreases over time. This can be done by simply assuming that $r_2 = (1-\mu)r$ with $0 < \mu < 1$ and substituting it into the equation (12). Direct inspection shows that μ affects only the option value

$$O_{q_1}(q_1, x) \equiv \int_{\beta^*}^{+\infty} \frac{\gamma}{\alpha}[\alpha(x+\gamma q_1)C_{x_2x_2}((x+\gamma q_1), \beta) - (1-\mu)r]d\Phi(\beta) \geq 0$$

where β^* is evaluated by (6) taking account of the lower cost $(1-\mu)r$. The derivative of O_{q_1} with respect to μ gives

$$\frac{\partial O_{q_1}(q_1, x)}{\partial \mu} = r(1-\Phi(\beta^*)) - \frac{\gamma}{\alpha}[\alpha(x+\gamma q_1)C_{x_2x_2}((x+\gamma q_1), \beta^*) - (1-\mu)r]\frac{\partial \beta^*}{\partial \mu} < 0 \tag{16}$$

and, since $\frac{\partial \beta^*}{\partial \mu} < 0$, we can conclude (see Figure 2):

Corollary 2 *The investment in period 1 decreases as the cost in period 2 decreases*

$$\frac{dq_1}{d\mu} < 0$$

except when $\alpha = 0$ *where the effect is nil:*

$$\frac{dq_1(\alpha = 0)}{d\mu} = 0$$

Proof. Straightforward from (12), (16) and proposition 2. ■

The second part of the corollary follows from the fact that $\alpha = 0$ eliminates the option value to delay the investment by the hospital and for this reason there is no advantage in waiting to invest.

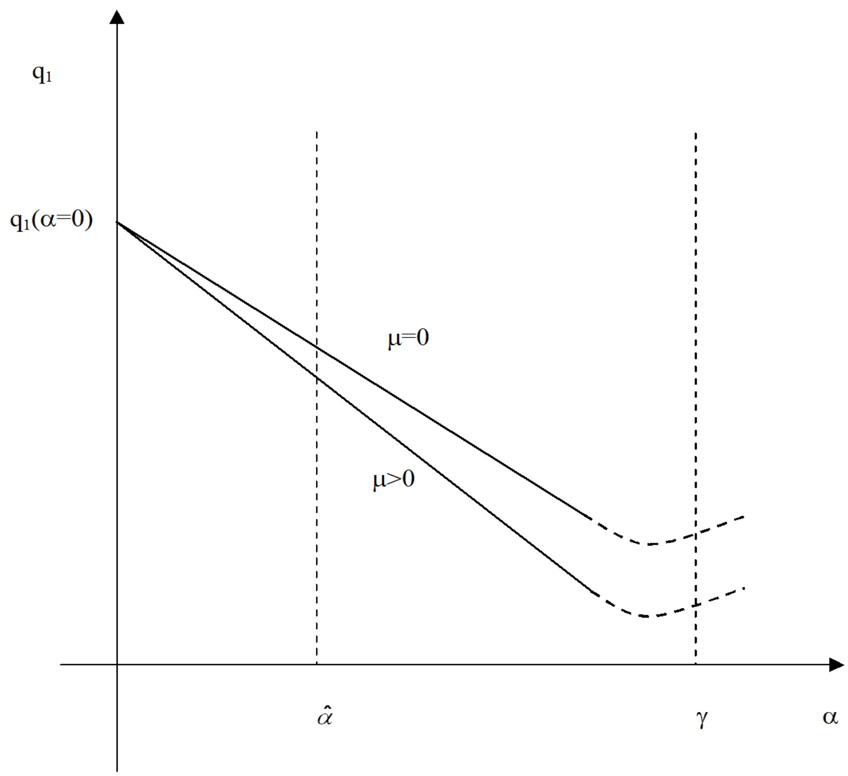

figure 2

5 Conclusions

This paper examines the relationship between purchasing rules and medical quality when quality depends on an irreversible investment decision. The level of investment is observable ex post while costs are subject to uncertainty. We concentrate on the response of a representative hospital to different purchasing rules set by the purchaser. The hospital is a surplus maximising unit that has to take decisions in a two-period model in a context of uncertainty and asymmetry of information. Uncertainty has several dimensions that relate to the cost of provision and to the innovation process while asymmetry of information derives from the observation of quality of health care only ex post. We define quality as an investment decision in health technology that produces a positive externality in the first period of its application. The investment is in fact assumed to be innovative only in the first period of its application when costs are higher due to the learning process. In the following period the hospital faces only set-up and/or expansion costs. We show that a trade-off exists between the duration of the contract and quality. In particular a one-period short-term contract is not effective in promoting investments in innovative technology, as one might expect. The purchasing rule chosen is also very important. We show that the most effective incentive to investing in new technology is to make the number of patients to be treated by a hospital depend only on the level of investment in the first period. In this case the purchaser gives a sort of patent to the hospital that has first invested in the new technology since those who invest in later periods will not see any increase in the number of cases they may treat. This patent is able to cancel out the hospital's option value to delay the investment. This policy can be applied only in a context where patients' choice is ruled out. If patients could choose where to go, the purchaser would not be able to control the flow of patients going to different hospitals and the incentive to invest might be reduced. This consideration opens up the discussion on another topical theme in health economics, i.e. patients' choice and its consequences on the system. From this analysis it seems that a trade-off might exist between the level of investment and patients' choices, but these effects should be explored further. Several other extensions can be proposed. In our paper the purchaser does not play an active role: the further logical step in our analysis would be to define an objective function for the purchaser and to find the optimal contract in this environment. The effect of different pricing rules could also be studied. In our model, in fact, we assume that the provider is reimbursed using a marginal cost pricing rule, but in health care prospective, mixed and incentive compatible payment systems are also used.

A Proof of Lemma 1

Let's first describe the properties of the hospital's surplus function (5). From (**??**), (3), (4) and (5), easy computation shows that at $t = 1$ we get:

$$U^1(q_1, x) \equiv \theta(q_1)[xC_x(x) - C(x)] > 0, \tag{17}$$

with the properties:

$$U^1_{q_1}(q_1, x) \equiv \theta'(q_1)[xC_x(x) - C(x)] > 0, \tag{18}$$

$$U^1_{q_1q_1}(q_1, x) \equiv \theta''(q_1)[xC_x(x) - C(x)] < 0. \tag{19}$$

At $t = 2$, the hospital's surplus is:

$$U^2(q_2, q_{1,}x, \beta) \equiv x_2(q_1, q_2)C_{x_2}(x_2(q_1, q_2), \beta) - C(x_2(q_1, q_2), \beta), \tag{20}$$

with $x_2(q_1, q_2) \equiv x + \gamma q_1 + \alpha(q_2 - q_1)$ and the properties:

$$U^2_{q_2} \equiv \alpha x_2(q_1, q_2)C_{x_2x_2}(x_2(q_1, q_2), \beta) > 0, \tag{21}$$

$$U^2_{q_2q_2} \equiv \alpha^2[C_{x_2x_2} + x_2(q_1, q_2)C_{x_2x_2x_2}] < 0, \tag{22}$$

and:

$$U^2_{q_1} \equiv \begin{cases} \gamma(x + \gamma q_1)C_{x_2x_2}((x + \gamma q_1), \beta) > 0 & \text{for} \quad q_2 = q_1 \\ (\gamma - \alpha)(x_2(q_1, q_2))C_{x_2x_2}(x_2(q_1, q_2), \beta) \geq 0 & \quad\quad q_2 > q_1 \end{cases} \tag{23}$$

$$U^2_{q_1q_1} \equiv \begin{cases} \gamma^2[C_{x_2x_2} + (x + \gamma q_1)C_{x_2x_2x_2}] < 0 & \text{for} \quad q_2 = q_1 \\ (\gamma - \alpha)^2[C_{x_2x_2} + x_2(q_1, q_2)C_{x_2x_2x_2}] \leq 0 & \quad\quad q_2 > q_1 \end{cases} \tag{24}$$

Note that an increase in q_2 determines an increase in the marginal costs $C_{x_2x_2}$, plus reduction in the revenue obtained from the infra-marginal patients $x_2C_{x_2x_2x_2}$. Condition (4) assures that the latter outweighs the former. Finally:

$$U^2_{q_2\beta} \equiv \alpha(x_2(q_1, q_2))C_{x_2x_2\beta}(x_2(q_1, q_2), \beta) > 0 \tag{25}$$

Since the value of the hospital's investment is:

$$V(q_1,x) \equiv U^1(q_1,x) + \delta \left\{ \int_0^{\beta^*} U^2(q_1,x,\beta) d\Phi(\beta) \right. \tag{26}$$

$$\left. + \int_{\beta^*}^{+\infty} \{U^2(q_2(\beta),q_1,x,\beta) - r[q_2(\beta)-q_1]\ \} d\Phi(\beta) \right\}$$

by direct substitution of (17) and (20), we obtain (8) in the text.

B Proof of proposition 1

>From (26), the first order condition for a maximum yields:

$$V_{q_1}(q_1,x) \equiv U^1_{q_1}(q_1,x)$$

$$+\delta \left\{ \int_0^{\beta^*} U^2_{q_1}(q_1,x,\beta)d\Phi(\beta) + \int_{\beta^*}^{+\infty} U^2_{q_1}(q_2(\beta),q_1,x,\beta)d\Phi(\beta) + r(1-\Phi(\beta^*)) \right\}$$

$$+\delta \left\{ U^2(q_1,x,\beta^*)\frac{d\beta^*}{dq_1} - \{U^2(q_2(\beta^*),q_1,x,\beta^*) - r[q_2(\beta^*)-q_1]\ \}\frac{d\beta^*}{dq_1} \right\} = r$$

Since by definition $U^2_{q_2}(q_1,x,\beta^*) = r$ which implies that $q_2(\beta^*) = q_1$, the above f.o.c. reduces to:

$$V_{q_1}(q_1,x) \quad \equiv \quad U^1_{q_1}(q_1,x) \tag{27}$$

$$+\delta \left\{ \int_0^{\beta^*} U^2_{q_1}(q_1,x,\beta)d\Phi(\beta) + \int_{\beta^*}^{+\infty} U^2_{q_1}(q_2(\beta),q_1,x,\beta)d\Phi(\beta) + r(1-\Phi(\beta^*)) \right\}$$

$$\equiv \theta'(q_1)[xC_x(x) - C(x)] + \delta \left\{ \int_0^{\beta^*} \gamma(x+\gamma q_1)C_{x_2x_2}((x+\gamma q_1),\beta)d\Phi(\beta) \right.$$

$$+\int_{\beta^*}^{+\infty}(\gamma-\alpha)(x_2(q_1,q_2(\beta)))C_{x_2x_2}(x_2(q_1,q_2(\beta)),\beta)d\Phi(\beta)+r(1-\Phi(\beta^*))\Bigg\}=r.$$

However, since $U^2_{q_2}(q_2(\beta),q_1,x,\beta)=r$, by (21) and (23) we can simplify (27) to:

$$V_{q_1}(q_1,x)\equiv\theta'(q_1)[xC_x(x)-C(x)]+\delta\Bigg\{\int_0^{\beta^*}\gamma(x+\gamma q_1)C_{x_2x_2}((x+\gamma q_1),\beta)d\Phi(\beta)$$
$$+\int_{\beta^*}^{+\infty}\gamma(x_2(q_1,q_2(\beta)))C_{x_2x_2}(x_2(q_1,q_2(\beta)),\beta)d\Phi(\beta)\Bigg\}=r. \tag{28}$$

Moreover, since by (24)

$$V_{q_1q_1}(q_1,x)\equiv U^1_{q_1q_1}(q_1,x)+\delta\Bigg\{\int_0^{\beta^*}U^2_{q_1q_1}(q_1,x,\beta)d\Phi(\beta)+\int_{\beta^*}^{+\infty}U^2_{q_1q_1}(q_2(\beta),q_1,x,\beta)d\Phi(\beta)\Bigg\}<0$$

for any given value of r, a unique value of q_1 exists satisfying equation (28). This proves the proposition.

C Proof of Lemma 2

Easy computation shows that (26) can be written as:

$$V(q_1,x)\equiv U^1(q_1,x)+\delta\int_0^{+\infty}U^2(q_1,x,\beta)d\Phi(\beta) \tag{29}$$
$$+\delta\int_{\beta^*}^{+\infty}\{-[U^2(q_2(\beta),q_1,x,\beta)-rq_2(\beta)]+[U^2(q_1,x,\beta)-rq_1]\}d\Phi(\beta).$$

Then, defining:

$$G(q_1,x)\equiv U^1(q_1,x)+\delta\int_0^{+\infty}U^2(q_1,x,\beta)d\Phi(\beta),$$

$$O(q_1, x) \equiv \int_{\beta^*}^{+\infty} \{-[U^2(q_2(\beta), q_1, x, \beta) - rq_2(\beta)] + [U^2(q_1, x, \beta) - rq_1]\} d\Phi(\beta)$$

and substituting (17) and (20), we obtain the expression in the text.

D Proof of proposition 2

First of all direct inspection of (8) and (11) shows that $G_{q_1}(q_1, x) = V_{q_1}(q_1, x; \alpha = 0)$. Secondly, if $\gamma = \alpha$ the purchasing rule becomes $x_2 = x + \alpha q_2$. According to the condition $U^2_{q_2}(q_2(\beta), q_1, x, \beta) = r$ the necessary condition for a maximum (10) reduces to:

$$V_{q_1}(q_1, x; \gamma = \alpha) \tag{30}$$

$$\equiv \quad \theta'(q_1)[xC_x(x) - C(x)] + \delta \left\{ \int_0^{\beta^*} \alpha(x + \alpha q_1) C_{x_2 x_2}((x + \alpha q_1), \beta) d\Phi(\beta) \right.$$

$$\left. + r(1 - \Phi(\beta^*)) \right\}$$

$$\equiv \theta'(q_1)[xC_x(x) - C(x)] + \delta \left\{ \int_0^{+\infty} \alpha(x + \alpha q_1) C_{x_2 x_2}((x + \alpha q_1), \beta) d\Phi(\beta) \right.$$

$$\left. - \int_{\beta^*}^{+\infty} [\alpha(x + \alpha q_1) C_{x_2 x_2}((x + \alpha q_1), \beta) - r] d\Phi(\beta) \right\} = r$$

where β^* is given by (6) under $\gamma = \alpha$. Comparing (30) with (12) confirms that $V_{q_1}(q_1, x; \alpha = \gamma) = G_{q_1}(q_1, x) - \delta O_{q_1}(q_1, x)$, which implies that $q_1(\gamma = \alpha) < q_1(\alpha = 0)$. Thirdly, as $V_{q_1}(q_1, x; \gamma = 0) < V_{q_1}(q_1, x; \alpha = \gamma)$ we get the first part of the inequality. This concludes the proof of the proposition.

References

[1] Abel, A.B., A.K. Dixit, J.C. Eberly and Pindyck R.S. (1996), “Options, the value of capital, and investment”, *Quarterly Journal of Economics*, 111(446), 753-777.

[2] Baker, L.C and Phibss, C.S.(2002), "Managed care, technology adoption, and health care: The adoption of neonatal intensive care", *RAND Journal of Economics*, 33(3), 524-48

[3] Baker, L.C and Phibss, C.S.(2002), "Managed care and technology adoption in health care:evidence from Magnetic Resonance Imaging , *Journal of Health Economics*, 20(3), 395-421

[4] Bergstrom, Blume, and H. Varian (1986) On the private provision of public goods, *Journal of Public Economics* 29, 25-49

[5] Biglaiser, G. and Ma, C.A. (2003), “ Price and quality competition under adverse selection: Market organization and efficiency, *Rand Journal of Economics,* 34(2), 266-286.

[6] Bös, D. and De Fraja, G. (2002), “Quality and outside capacity in the provision of health services”, *Journal of Public Economics*, 84, 2, 199-218.

[7] Brennan, M.J., and E.S. Schwartz, (1985), “Evaluating Natural Resource Investments”, *The Journal of Business*, 58, 2, pp. 137-157.

[8] Chalkley, M. and Malcomson, J.H. (2000), “Government purchasing of health services”, in Culyer, A.J. and Newhouse, J.P. (eds.), *Handbook of Health Economics*, North-Holland, 461-536.

[9] Chalkley, M. and Malcomson, J.H. (2002), "Cost sharing in health service provision: an empirical assessment of cost saving", *Journal of Health Economics*, 84, 219-249.

[10] Chalkley, M. and Malcomson, J.H. (2000), "Contracting for health services with unmonitored quality", *Economic Journal*, 108(449), 1093-1101.

[11] Dixit, A. (1990), *Optimization in economic theory*, Oxford: Oxford University Press.

[12] Dixit A., (1992), "Investment and Hysteresis" *Journal of Economic Perspectives,* **6**, 107-132.

[13] Dixit, A. and Pindyck R.S (1994), *Investment under uncertainty*, Princeton: Princeton University Press.

[14] Docteur, E. and Oxley, H. (2003), Health-care systems: lessons from the reformed experience, *Working Paper n. 374, Economics Department*, OECD, Paris

[15] Driffield and P.C. Smith (2006) Medical Decision Making

[16] Ellis R (1997), "Creaming, skimping and dumping: provider competition on intensive and extensive margins", *Journal of Health Economics*, vol.17, 537-555.

[17] Einthoven, A. (2002), "American health care in the 1990s: Some lessons for the Europeans", Paper presented at the 4th European conference on health economics, Paris, 7-10 July.

[18] Gaynor, M. and W.B. Vogt. (2003). "Competition among Hospitals." *Rand Journal of Economics* 34(4), 764-85

[19] Gravelle, H. (1999), "Capitation contracts: Access and quality", *Journal of Health Economics*, 18, 315-340.

[20] Gravelle, H. and Masiero, G. (2000), "Quality incentives in a regulated market with imperfect information a switching costs: capitation in general practice", mimeo.

[21] HTC - Health Tecnology Centre (2003) Technology and quality: consideration for adoption and diffusion. A literature review.*mimeo*

[22] Kessler, D.P. and McClellan, B. (2000), "Is hospital competition socially wasteful?", *Quarterly Journal of Economics*, 115(2), 577-615.

[23] Laffont, J.J. and Martimort, D. (2002), *The theory of incentives*, Princeton: Princeton University Press.

[24] Levaggi, R. (2003), "Asymmetry of information in a mixed oligopoly market for health care"*, mimeo.*

[25] Levaggi, R. (2005), "Hospital health care: cost reimbursement and quality control in a spatial model with asymmetry of information", *International Journal of Health Care Finance and Economics*,

[26] Levaggi, R. (2007) Regulating internal markets for hospital care, *Journal of Regulatory Economics*, forthcoming

[27] Levaggi, R. (1999), "Optimal procurement contracts under a binding budget constraint", *Public Choice* , 101(1-2), 23-37.

[28] Levaggi, R. (1996), "NHS contracts: an agency approach", *Health Economics*, 5, 341-352.

[29] Levaggi, R. and Rochaix, L. (2004), "Exit or loyalty? Patient driven competition in ambulatory care", mimeo.

[30] Levaggi, R., Moretto, M., and Rebba, V. (2005), "Investment Decisions in Hospital Technology When Physicians are Devoted Workers", Working paper n 85-2005, FEEM, Milan,

[31] Ma, C. A. (1994), "Health care payment systems: costs and quality incentives", *Journal of Economics and Management Strategy*, vol.3(1), 93-112.

[32] MEDTAP International (2004). The Value of Investment in Health Care. Bethesda, MD: 2004. Available at: http://www.medtap.com/Products/HP_FullReport.pdf

[33] McDonald, R., and D.R. Siegel, (1986), "The Value of Waiting to Invest", *The Quarterly Journal of Economics*, 101, pp. 707-728.

[34] Palmer, S. and Smith P.C. (2000), "Incorporating option values into the economic evaluation of health care technologies", *Journal of Health Economics*, 19(5), 755-66.

[35] Pindyck R., (1991), "Irreversibility, Uncertainty and Investment", *Journal of Economic Literature*, **29**, 1110-1152.

[36] Sloan, F.A., Picone, G.A., Taylor, D.H., Chou, S.-Y (2000), "Hospital ownership and cost and quality of care: is there a dime's worth of difference?", Working paper 00-11, Department of Economics, Duke University.