1. Introduction

One of the most studied topics in industrial organisation is the relationship between market structure and incentives to innovate (for a general survey, see, among others, Kamien and Schwartz (1982)). Since the seminal works of Schumpeter (1937) and Arrow (1962), economists have recognised that the innovation process is crucially dependent on the strategic environment in which firms operate and on the institutional arrangements which govern the appropriability of economic returns from innovation (see, among others, Tirole (1988) and Reinganum (1987) for a general introduction). In this paper we focus on one particular aspect of the relationship between market structure and innovation, that is the effect of regulation on the incentives to innovate of a regulated firm. More precisely, we want to discuss the influence of price regulation on the economic incentives to undertake costly R&D effort to discover a new technology.

The influence of price regulation on the innovative activity of regulated firms is one of the main issues to be tackled in assessing the advantages of alternative forms of regulation (for a general discussion on the theory of regulatory instruments, see Laffont and Tirole (1993)). In particular, the UK privatisation and regulation experiences (see Vickers and Yarrow (1988) and Amstrong et. al (1994) for a detailed evaluation) have been particularly important in bringing to the attention of industrial economists and policy-makers the relevance of price regulation as a tool for fostering innovative activity and efficiency improvements (see, for instance, the 1989 Rand Symposium on Price Cap Regulation). Following a policy perspective, we will thus examine alternative schemes of price regulation and their effects on the incentives for a regulated monopoly to innovate. In this respect, we will not pursue the line of the ‘new theory of regulation’ (Laffont (1994)), but we will try and address a simple positive problem: that is, whether some observed schemes of price regulation can be evaluated, from an economic theory viewpoint, to be beneficial to social welfare through the improvement of productive efficiency in regulated industries.

This paper is organised as follows. The next section is devoted to a discussion of positive approaches to regulation and their relevance for the policy debate about the relationship between innovative activity and regulation. Section three introduces the framework of analysis, reviewing some results of the literature on incentives to innovate in monopolistic markets. Section four presents the general analysis of price regulatory schemes in terms of incentives to undertake R&D effort, comparing a traditional price cap scheme with a downward flexible price-cap scheme. The welfare analysis of these schemes and a discussion of their relative merits are presented in section five. Section six is dedicated to a comparison between the incentives to innovate resulting from a price cap type of regulation and those obtained using the so-called 'sliding scales' regulatory schemes. Section seven offers some concluding remarks and comments about possible directions of further work in this area.

2. Good regulatory regimes

The recent advances in the theory of optimal regulatory regimes have mainly focused on the qualitative features of optimal regulatory institutions[1]. The difficulty in translating the predictions of this research approach into simple rules for actual policy-making contrasts sharply with the influence of the earlier Ramsey pricing literature on regulatory institutions[2]. In fact, the literature on Ramsey pricing provides simple rules for regulators to follow, rules which do not require them to make transfers or to impose taxes on the regulated firms. This somewhat paradoxical state of affairs creates a problem for industrial economists interested in either examining or formulating 'good regimes' which could be implemented in practice. In this perspective, Schmalensee (1989) has proposed a framework for the analysis of 'good' regulatory regimes which encompass cost-plus regulation and some forms of price cap regulation. He uses a simulation study to try and assess the different properties of these second best mechanisms and he finds that when there is no uncertainty, price cap regimes are often 'optimal', and even more so when the weight of profits is higher in the social welfare function. This way of proceeding has two interesting implications. First, it represents an alternative route to exploring the properties of second-best models, which would be too complicated to be analytically discussed[3]. Second, it may provide some policy indications to regulators as to how to model and calibrate their proposed regulatory schemes.

Following a similar line of reasoning, we would like to discuss an important policy aspect of alternative regulatory schemes, that is, the effects of price regulation on the incentives to innovate for a regulated firm. Cabral and Riordan (1989) have examined the effects of different forms of price regulation in terms of promotion of cost-reducing

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[1] For an excellent survey, see Baron (1989), and Laffont and Tirole (1993) for a more general treatment.

[2] For a discussion of this point, see Faulhaber and Baumol (1988).

[3] Gasmi et al. (1994) take as a point of departure of their analysis of different regulatory regimes the grid of parameters built by Schmalensee (1989) (for a discussion of their results, see section 6).

investments. In particular, they have compared price cap regulation to cost based regulation. Incentives for cost reduction are provided by both types of regulation. Under price cap regulation the firm appropriates the gains from cost reduction if it manages to reduce costs to below the price ceiling fixed by the regulatory authority. Moreover, if the innovation is drastic (i.e the new monopoly price is below the previous cost level), it can manage to extract extra profits by charging the monopoly price and still be in compliance with price regulation. The first result of their analysis is that price regulation induces a greater effort level with respect to the case of an unregulated monopolist. The intuition of this result follows from the so-called Arrow effect (Arrow, 1962). Since monopoly output is smaller (price is higher) than the competitive output, the gains from a reduction in the cost level are distributed among a smaller number of units. The introduction of a price cap forces the monopolist to set a price lower than its monopoly price, so it obliges him to produce a higher quantity. By so doing, price regulation increases the incentives for successful innovation. A corollary of this point is that, by lowering the price cap, the regulator induces greater R&D effort by the monopolist (until the profit constraint for the firm is not binding). Moreover, Cabral and Riordan show that price cap regulation leads to a greater effort in cost reduction than cost-based regulation (however, since the effect on consumers' surplus is ambiguous, the total welfare comparison between the two regimes is not complete). In the following sections we present a model which extends the Cabral and Riordan analysis to evaluate the welfare properties of price regulation with regards to incentives to innovate.

3. Incentives to innovate in unregulated monopoly

In this section we introduce the framework to analyse the incentives to innovate in an unregulated monopoly while the next section develops a model, following Clemenz (1991), which discusses the effect of a downward flexible price cap on the innovation choices of a regulated firm.

Consider a monopoly market with a single homogeneous good. At the same time we assume the existance of a benevolent social maximizer, so that we can define a social utility function $u(q)$, with $u'>0>u''$, where q indicates the quantity consumed in the market and $u'(q)$ denotes the first derivative of the social utility function with respect to its argument. Then, the equilibrium price can be defined as $p(q)=u'(q)$.

The market is characterised by a technology with constant average and marginal cost, that we indicate by c_0. Suppose it is possible to invest in cost-reducing R&D obtaining a new technology with a lower cost level. However, the new cost level is a random variable distributed in the interval $[0,c_0]$, according to a known probability distribution function F(c,e), which depends on the effort invested in cost reducing activities, indicated by e. In particular, we assume that the distribution function has the following properties:

(i) $F(0,e) = 0$ and $F(c_0,e) = 1$;

(ii) $F_e(c,e) \geq 0 \geq F_{ee}(c,e)$

where $F_e(c,e)$ and $F_{ee}(c,e)$ denote the first and the second derivatives of the cumulative distribution function with respect to effort. Assumption (i) requires no explanation, whereas assumption (ii) indicates that higher effort increases the probability of a low cost realisation, but at a decreasing rate.

Consider first the choices of a benevolent social planner. In this case, considering also the cost of R&D effort, social net utility becomes

$$u(q) - c\, q - \psi(e)$$

where $\psi(e)$ denotes the disutility of cost reducing effort. In the following we assume that $\psi'(e)>0$ and $\psi''(e) \geq 0$.

In general, as shown by Dasgupta and Stiglitz (1980), the social value of given cost reduction from c_0 to c_1 can be defined as

$$\int_{c_1}^{c_0} q_S(c)dc$$

where $q_S(c)$ indicates the socially optimal level of output for a given cost c. When cost reduction is uncertain, c is a random variable which can take any value in the interval $[0,c_0]$, according to the cumulative distribution function F(c,e). Then, the expected social value of cost reduction, gross of the disutility of effort, becomes

$$V_S\,(c_0\,;c) = \int_{0}^{c_0} q_S(c)F(c;e)dc$$

The socially optimal level of cost-reducing effort is then determined in order to maximise the net expected social value of cost reduction, that is

$$V_S(c_0;c) = \int_0^{c_0} q_S(c)F(c;e)dc - \psi(e)$$

implying the first order condition

$$\int_0^{c_0} q_S(c)F_e(c;e)dc = \psi'(e)$$

Then, define as e_S the level of effort which satisfies the first order condition. Clearly, the second order condition for a maximum, that is

$$\int_0^{c_0} q_S(c)F_{ee}(c;e)dc - \psi''(e)$$

is satisfied since $F_{ee} \leq 0$ and $\psi'' \geq 0$.

Consider now the the choices of a monopolist. Given an initial cost level c_0, the monopolist's profits can be written as

$$\pi_m(c_0) = [p(q) - c_0]\, q$$

We can define the profit maximising quantity chosen by the monopolist as q_m. The expected gain from a cost reduction from c_0 to c_1 would be defined as

$$V_m(c_0;c) = \int_0^{c_0} q_m(c)F(c;e)dc$$

In order to maximise its expected gains from cost reduction, the monopolist would choose effort to maximise

$$V_m(c_0;c) = \int_0^{c_0} q_m(c)F(c;e)dc - \psi(e)$$

implying the first order condition

$$\int_0^{c_0} q_m(c)F_e(c;e)dc = \psi'(e)$$

Then, define as e_m the level of effort which satisfies the first order condition for the monopolist. Since $q_m<q_S$, and $F_{ee}\leq 0$, it is clear that the cost-reducing effort chosen by the

monopolist is too low with respect to the social optimal level. Moreover, the monopolist also distorts the price level, so there is scope for regulation in order to tackle both the productive and allocative distortions induced by the monopolist.

4. Price regulation and incentives to innovate

4.1 The basic framework

The aim of this model is to analyse whether a flexible (downward) price cap can be superior in terms of inducing cost-reducing effort in the regulated firm with respect to a traditional price cap regulation. Moreover, it would be important to evaluate whether this flexible cap is superior, in terms of social welfare (or consumer surplus).

The timing of the model is as follows. As before, consider a regulated monopoly with initial constant marginal cost c_0 (which is equal to the initial regulated price). This unit cost is independent of quantity, but is influenced by the cost-reducing effort chosen by the firm according to the distribution function F(c,e). The initial cost level is observable by the regulator, so we do not have any adverse selection problem. Having observed the initial cost level, the regulator introduces a regulatory pricing scheme based on the new cost level, which will be determined on the basis of the firm's cost-reducing effort. Given the regulatory scheme, the firms chooses its level of effort in order to maximise expected profits. After the new cost level is realised, the regulatory scheme enters in action. It should also be stressed that also the new cost level is observable by both the regulator and the firm. Then, the firm chooses its profit maximising level of output and profits are realised.

Two points should be mentioned here. First, since the regulatory model is built as a one-shot game, and it implicitly analyses only the short-run effects of price regulation on incentives to innovate. In reality, regulatory games are typically multiperiod games, so that it would be important to extend this simple model to a multiperiod setting, and in this sense, the timing of regulatory review would also become crucial. Second, another important assumption is that no drastic innovation is possible. In other terms, the unregulated profit maximising price p_m is always greater than the initial cost c_0 for any cost realisation. This implies that the regulatory pricing schedule is always binding for the firm (for a brief discussion of this point, see the last section).

4.2 Price cap regulation

Following the framework proposed by Clemenz (1991), we will first discuss the introduction of a price cap regulatory scheme. In this case the regulatory pricing scheme is very simple. The regulator fixes a price cap $p_c \leq c_0$. If the new observed cost is lower than p_c than the firm is allowed to set a price not higher than p_c. If it is higher than the price cap, then the regulator allows a price equal cost. In short, this type of regulatory scheme can be summarised as a pricing schedule $P(p_c,c)$ such that

$$P(p_c,c) = \max \{p_c, c\}$$

In order to maximise its profits, the monopolist would choose its output level to maximise

$$\pi = [p(q) - c]\, q$$

subject to the condition that $p(q) \leq P(p_c,c)$. This solution is denoted as $q(p_c,c)$. Note that $q(p_c,c)$ is decreasing both in p_c and in c. Thus, the firm chooses its optimal effort level in order to maximise expected profits defined as

$$V_p(p_c) = \int_0^{p_c} q(p_c;c)F(c;e)dc - \psi(e) \qquad (1)$$

subject to the non-negativity constraint $V_p(p_c) \geq 0$. This implies the first order condition

$$\int_0^{p_c} q(p_c;c)F_e(c;e)dc = \psi'(e) \qquad (2)$$

Then, define as $e(p_c)$ the level of effort which satisfies the first order condition for the regulated monopolist under price cap.

Fact 1: a regulated monopolist invests more in effort reduction than an unregulated monopolist (this result follows immediately by comparing $e(p_c)$ with e_m, for p_c sufficiently close to c_0).

The intuition is as follows: as the monopolist's optimal price is bound by p_c, it is clear than the quantity produced is higher so that a given level of cost-reducing effort is greater for the regulated firm. Thus, the 'Arrow effect' is also found in the case of uncertain cost reduction (Cabral and Riordan (1989) already proved this result in the case of cost certainty).

An important point to analyse is how incentives to innovate are influenced by the introduction of the price cap. By differentiating (2) with respect to p_c we get

$$\delta^2 V_p/\delta e \delta\, p_c = \int_0^{p_c} q_1(p_c;c)F_e(c;e)dc + q(p_c;p_c)F_e(p_c;e) \qquad (3)$$

where $q_1(p_c;c)$ denotes the derivative of $q(p_c;c)$ with respect to its first argument. In order to be able to discuss the effect of a price cap on the optimal effort level, we have to discuss the sign of the previous expression. Since $q_1(p_c,c)$ is negative and F_e is non-negative, the sign of the expression depends on the magnitude of the second term on the right hand side of the expression (3). In general, this term is positive, so that the sign of the derivative depends on the relative size of the two terms on the right hand side. For p_c close to c_0, we have that $F_e(c_0,e)$ is close to zero (remember that F is a concave function of effort) and the sign of the derivative becomes negative. So, a reduction of the price cap increases the optimal level of effort chosen by the firm. The effect of reductions in the price cap level and the optimal effort chosen by the firm is summarised in the following fact.

Fact 2: a reduction of the price cap induces a higher level of cost reducing effort (at least for a price cap sufficiently close to the initial cost level).

This result implies an immediate comparison between the relative incentives induced by price cap regulation compared to cost based regulation (where the regulator fixes the price equal to the initial cost level and keeps it there until the following price review). This comparison is summarised by the following fact.

Fact 3: price cap regulation has a stronger effect on the optimal level of cost reducing effort than cost based regulation (cost based regulation is defined as a price equal to the initial cost level).

This result depends on the fact that, as was mentioned before, the price cap can always be chosen sufficiently close to the initial cost level to ensure expected positive profits for the firm and to induce the firm to choose a higher level of cost reducing effort.

It is not immediate, however, to establish a clear relationship between reduction of the price cap and effort levels without specifying the distribution function of cost reduction. In other words, it is not possible to conclude that the relationship between p_c and effort is monotonic, in the sense that effort increases up to the point that (3) equals zero, and then declines (see Clemenz (1991) for a discussion of this point).

4.3 Flexible-cap regulation

In this case the regulatory pricing scheme is defined as follows

$$P(p_c, \alpha, c) = \max \{c, \min (p_c, c(1+\alpha)\}$$

where α is a non-negative constant. More intuitively, the regulator initially fixes a price cap $p_c \le c_0$. If the new observed cost belongs to the interval $[0,c_1]$, where $c_1=p_c/(1+\alpha)$ the firm is allowed to set a price not greater than $p_\alpha=(1+\alpha)c$. For c in the interval $[c_1,c_2]$, where $c_2=p_c$, the firm is allowed to set a price not higher than p_c. If c is higher than the price cap, then the regulator allows for a price equal to cost. Clearly, as $\alpha \to \infty$ we go back to the price cap regulatory regime (for a graphical illustration of these regulatory regimes, see figure 1).

[Insert figure 1 about here]

The profit maximising choices of the monopolist can be described as follows. When the cost realisation is such as $0<c\le c_1$, the monopolist would choose its output level to maximise

$$\pi = [p(q) - c]\, q$$

subject to the condition that $p(q)\le p_\alpha$. Denote the optimal level of output in this case as $q(p_\alpha,c)$. Note that $q(p_\alpha,c)$ is decreasing both in p_α and in c.

When the cost realisation is such as $c_1\le c\le c_2$, the monopolist would choose its output level to maximise profits subject to the condition that $p(q)\le p_c$. Denote the optimal level of output in this case as $q(p_c,c)$. Note that $q(p_c,c)$ is decreasing both in p_c and in c.

Thus, the firm chooses its optimal effort level in order to maximise expected profits

$$V_p (p_\alpha;\alpha)= \int_0^{c_1} q(p_\alpha;c)F(c;e)dc + \int_{c_1}^{c_2} q(p_c;c)F(c;e)dc - \psi(e) \qquad (4)$$

implying the first order condition for an interior solution (i.e. e>0)

$$\int_0^{c_1} q(p_\alpha;c)F_e(c;e)dc + \int_{c_1}^{c_2} q(p_c;c)F_e(c;e)dc = \psi'(e) \qquad (5)$$

Then, define as $e(p_c,\alpha)$ the level of effort which satisfies the first order condition for the regulated monopolist under flexible price cap.

At this point, it would be interesting to compare this optimal effort level with that of a price cap regulatory regime. However, this comparison is not possible without taking into account the effect of this new regime on the incentives to innovate and on firms' profits. We will turn now to these two important issues.

First, consider how incentives to innovate are influenced by the introduction of the flexible-cap regime. We start by considering how incentives are affected by p_c. By differentiating (5) with respect to p_c we get

$$\delta^2 V_p/\delta e \delta p_c = \int_{c_1}^{c_2} q_1(p_c;c)F_e(c;e)dc + q(p_c;p_c)F_e(p_c;e) - q(p_c;c_1)F_e(c_1,e)(dc_1/dp_c) \quad (6)$$

The qualitative discussion of the effect of p_c is very similar to that carried out in the price cap case. In fact, comparing equations (6) and (3), we note that, apart from the different limits of integration, we have an additional term which is negative (since dc_1/dp_c is positive for finite values of α). So, for p_c sufficiently close to c_0, as in the previous case, a reduction of the price cap (for a given α) increases the effort level at the optimum. This effect is partially weakened because this incentive effect is valid only for the interval $[c_1, c_2]$ where the price cap is binding for the firm.

We can now examine how incentives to innovate are affected by α. By differentiating (5) with respect to α we get

$$\delta^2 V_p/\delta e \delta \alpha = \int_{0}^{c_1} q_1(p_\alpha;c)(dp_\alpha/d\alpha)F_e(c;e)dc + q(p_\alpha;c_1)F_e(c_1;e)(dc_1/d\alpha) \quad (7)$$

The qualitative discussion in this case is very simple. It follows that $de/d\alpha$ is always negative, since, for α finite, we have that $dc_1/d\alpha$ is negative. In other terms, a reduction in α increases, at the maximum, the effort chosen by the firm.

The second important point to discuss is the effect of the two regulatory instruments on profits. First, consider how expected profits are affected by p_c. We obtain

$$dV_p(p_c,\alpha)/dp_c = (\delta V_p/\delta e)(de/dp_c) + (\delta V_p/\delta p_c)$$

by the envelope theorem, at the profit maximizing choice of effort, thus,

$$dV_p/dp_c = \int_{c_1}^{c_2} q_1(p_c;c)F(c;e)dc + q(p_c;p_c)F(p_c;e) - q(p_c;c_1)F(c_1;e)(dc_1/dp_c) \qquad (8)$$

The change in profit for a given change in p_c has a positive sign. The sum of the first two terms on the left hand side is always positive (since it represents the expected marginal revenue for a change in price, see Clemenz, eq.(40)), and the third term is always smaller than the second. So, for α not too close to 0 (and this latter case in generally valid, also considering the effects of α on expected profits), the third term, although negative, has a second order effect on the sign of (8), since dc_1/dp_c is small, when α is sufficiently large. Thus, profits are always increasing with p_c, and this is intuitive since increasing p_c relaxes the price constraint on the firm. In the case of α positive, however, this effect is weakened because the profits' reduction is limited to the interval $[c_1, c_2]$ where the price cap is binding for the firm. Clearly, there will be a certain level of p_c such that, for lower price caps the firm will not find it more convenient to increase effort and will choose e=0 as a profit maximising choice.

Then, we turn to consider how expected profits are affected by α. By similar reasoning as before, we have that

$$dV_p/d\alpha = \int_{0}^{c_1} q_1(p_\alpha;c)(dp_\alpha/d\alpha)F(c;e)dc + q(p_\alpha;c_1)F(c_1;e)(dc_1/d\alpha) \qquad (9)$$

It is easy to see that profits are always decreasing with α, and this is intuitive since increasing α corresponds to a stronger price squeeze on the regulated firm. Clearly, as before, there will be a certain level of α such that the firm will not find it more convenient to increase effort and will choose as a profit maximising choice e=0.

5 Price regulation and incentives to innovate: welfare analysis

In this section we discuss the welfare properties of the previous regulatory schemes. Using the notation introduced in section 3, we define consumer surplus for a given quantity consumed q as

$$CS(q) = u(q) - p(q)q$$

In a monopoly, it is easy to establish (see Dasgupta and Stiglitz (1980) and Clemenz (1991)) that the change in consumer surplus induced by a change in cost can be written as

$$\delta CS/\delta c = u'(q)q'_m(c) - p'(q)q'_m(c)q_m(c) - p_m(c)q_m(c)$$

Since by assumption $u'(q)=p(q)$, we can then write

$$\delta CS/\delta c = -p'(q)q'_m(c)q_m(c) = p'_m(c)q_m(c)$$

where we define $p'_m(c) = -p'(q)q'_m(c)$ as the marginal price change induced by a marginal cost change for an unregulated monopolist.

In an unregulated monopoly, the increase in consumer surplus for a reduction in cost from c_0 to c' is defined as

$$CS_m(c_0;c') = \int_{c'}^{c_0} p'_m q_m(c)dc \qquad (10)$$

In case of uncertain cost reduction, the expected net consumer surplus is defined as

$$CS_m = \int_{0}^{c_0} p'_m q_m(c)F(c;e_m)dc \qquad (10')$$

where e_m is the effort chosen by the monopolist. The corresponding level of social welfare, also considering the monopolist's profits, is then defined as

$$W_m = \int_{0}^{c_0} p'_m q_m(c)F(c;e_m)dc + \int_{0}^{c_0} q_m(c)F(c;e_m)dc - \psi(e) \qquad (11)$$

or, alternatively,

$$W_m = \int_0^{c_0} (1+p'_m)q_m(c)F(c;e_m)dc - \psi(e)) \qquad (11')$$

since $p'_m(c) = -p'(q)q'_m(c) > 0$, it is clear that welfare is not maximised since the monopolist does not take into account consumer surplus when he chooses the level of output. Moreover, the level of effort is not socially efficient either.

5.1 Price cap regulation

Adapting the previous notation, we define as $p_2(p_c,c)$ the marginal price change corresponding to a marginal cost change if the firm cannot choose a price greater than p_c. It is clear that $p_2(p_c,c)$ is nondecreasing in p_c and c. In this case, the expected consumer surplus is defined as

$$CS(p_c) = \int_0^{c_2} p_2(p_c;c)q(p_c;c)F(c;e)dc + \int_{c_2}^{c_0} q_S(c)F(c;e)dc \qquad (12)$$

so that the social planner chooses p_c to maximise $CS(p_c)$. The corresponding first order condition is then

$$e'(p_c)[\int_0^{c_2} p_2(p_c;c)q(p_c;c)F_e(c;e)dc + \int_{c_2}^{c_0} q_S(c)Fe(c;e)dc] +$$

$$+\int_0^{c_2} p_2(p_c;c)q_1(p_c;c)F(c;e)dc = 0 \qquad (13)$$

where $e'(p_c)$ denotes the derivative of effort with respect to p_c. Following Clemenz, it is easy to see that, at the maximum, $e'(p_c)$ is positive. In fact the third term on the left hand side of (13) is negative, since q_1 is negative, and the two terms in parentheses are positive. This implies that, in order to maximise consumer surplus, the price cap should be set below the effort maximising level (if the non-negativity constraint for the firm's profits is not already binding).

Consider then the case of social welfare. Expected social welfare is defined as the sum of consumer surplus and firm's profit, that is

$$W(p_c)=\int_0^{c_2}[1+p_2(p_c;c)]q(p_c;c)F(c;e)dc+\int_{c_2}^{c_0}q_S(c)F(c;e)dc-\psi(e) \qquad (14)$$

The social planner chooses p_c to maximise $W(p_c)$. The corresponding first order condition is (considering firm's optimal choice of effort)

$$e'(p_c)[\int_0^{c_2}p_2(p_c;c)q(p_c;c)F_e(c;e)dc+\int_{c_2}^{c_0}q_S(c)F_e(c;e)dc]+$$

$$\int_0^{c_2}p_2(p_c;c)q_1(p_c;c)F(c;e)dc+\int_0^{c_2}q_1(p_c;c)F(c;e)dc+$$

$$+q(p_c;p_c)F(p_c;e)dc=0 \qquad (15)$$

Comparing (15) with (13), it is easy to see that there are two additional terms on the left hand side which capture the effect on expected profits of the change in p_c,. These terms sum up to a non-negative component. Clearly, then, if p_c is lowered, there is a decrease in expected profits (this effect was already discussed in the previous section with regard to the flexible-cap case). However, since output is closer to its first-best level, the increase in consumer surplus following a decrease in the price cap outweighs the induced loss in profits. This discussion of the welfare effects of the price cap regulation scheme can be summarised in the following fact.

Fact 4. In the price cap regulation scheme, the price cap which maximises social welfare has to be fixed either below (if it compatible with the expected profit constraint for the firm) or at the effort maximising level.

We now turn to the welfare properties of the other regulatory scheme.

5.2 Flexible cap regulation

By analogy with previous definitions, we define $p_1(p_\alpha,c)$ as the marginal price change corresponding to a marginal cost change if the firm cannot choose a price greater than p_α. It is clear that $p_1(p_\alpha,c)$ is nondecreasing in p_α and c. In this case, the expected consumer surplus is defined as

$$CS(p_c;\alpha)=\int_0^{c_1} p_1(p_\alpha;c)q(p_\alpha;c)F(c;e)dc+\int_{c_1}^{c_2} p_2(p_c;c)q(p_c;c)F(c,e)dc+$$

$$+\int_{c_2}^{c_0} q_S(c)F(c;e)dc \qquad (16)$$

so that the social planner chooses p_c and α to maximise $CS(p_c,\alpha)$. The corresponding first order condition with respect to p_c is

$$e_1(p_c;\alpha)[\int_0^{c_1} p_1(p_\alpha;c)q(p_\alpha;c)F_e(c;e)dc+\int_{c_1}^{c_2} p_2(p_c;c)q(p_c;c)F_e(c,e)dc+$$

$$+\int_{c_2}^{c_0} q_S(c)F_e(c;e)dc]+\int_{c_1}^{c_2} p_2(p_c;c)q_1(p_c;c)F(c;e)dc=0 \qquad (17)$$

where $e_1(p_c,\alpha)$ denotes the derivative of e with respect to p_c.

The first order condition with respect to α is

$$e_2(p_c;\alpha)[\int_0^{c_1} p_1(p_\alpha;c)q(p_\alpha;c)F_e(c;e)dc+\int_{c_1}^{c_2} p_2(p_c;c)q(p_c;c)F_e(c,e)dc+$$

$$+\int_{c_2}^{c_0} q_S(c)F_e(c;e)dc]+\int_0^{c_1} p_1(p_\alpha;c)q(p_\alpha;c)F(c;e)dc=0 \qquad (18)$$

where $e_2(p_c,\alpha)$ denotes the derivative of e with respect to α.

In this case, expected social welfare is defined as

$$W(p_\alpha;\alpha)=\int_0^{c_1} [1+p_1(p_\alpha;c)]q(p_\alpha;c)F(c;e)dc+\int_{c_1}^{c_2} [1+p_2(p_c;c)]q(p_c,c)F(c,e)dc+$$

$$+\int_{c_2}^{c_0} q_S(c)F(c;e)dc-\psi(e) \qquad (19)$$

The social planner chooses p_c and α to maximise $W(p_c,\alpha)$. The first order condition with respect to p_c is

$$e_1(p_c;\alpha)\left[\int_0^{c_1}[1+p_1(p_\alpha;c)]q(p_\alpha;c)F_e(c;e)dc+\int_{c_1}^{c_2}p_2(p_c;c)q(p_c,c)F_e(c,e)dc+\right.$$

$$\left.+\int_{c_2}^{c_0}q_S(c)F_e(c;e)dc\right]+\int_{c_1}^{c_2}p_2(p_c;c)q_1(p_c;c)F(c;e)dc+$$

$$+\int_{c_1}^{c_2}q_1(p_c;c)F(c;e)dc+q(p_c;p_c)F(p_c;e)-q(p_\alpha;c_1)F(c_1;e)(dp_\alpha/dc_1)=0 \qquad (20)$$

The first order condition of the social welfare maximisation with respect to α is

$$e_2(p_c;\alpha)\left[\int_0^{c_1}p_1(p_\alpha;c)]q(p_\alpha;c)F_e(c;e)dc+\int_{c_1}^{c_2}[1+p_2(p_c;c)]q(p_c,c)F_e(c,e)dc+\right.$$

$$\left.+\int_{c_2}^{c_0}q_S(c)F_e(c;e)dc\right]+\int_0^{c_1}p_1(p_\alpha;c)q_1(p_\alpha;c)(dp_\alpha/d\alpha)F(c;e)dc+$$

$$+\int_0^{c_1}q_1(p_\alpha;c)(dp_\alpha/d\alpha)F(c;e)dc+q(p_\alpha;c_1)F(c_1;e)(dc_1/d\alpha)=0 \qquad (21)$$

where $e_2(p_\alpha,\alpha)$ denotes the derivative of e with respect to α.

In this case the qualitative discussion follows the lines of the price cap regulatory scheme. However, since we have two instruments, it is not possible to define the optimal choice of one without considering the effects of the other on welfare, taking into account the constraints faced by the firm.

5.3 Welfare comparisons and discussion

The comparison between the welfare levels obtain under the two different regimes is not immediate. In fact, whereas in a price cap regime we are able to determine the sign of the effect of price on social welfare, here we have consider not only the effect of each parameter on social welfare but also the indirect effects. In other words, the total differential of social welfare with respect to α is given by the expression (21) but also depends on the effect on social welfare of p_c induced by a change in α. Since along the incentive constraint (i.e the optimal effort choice condition) the sign of the derivative of p_c with respect to α is negative, we have that the sign of the total effect of a change in α on social welfare is not determined a priori. It will depend, among other things, on the actual distribution function of cost realisations. So, we are not able to assess with precision the impact of a flexible cap on social welfare.

6. Flexible price regulation and sliding scales: a comparison

In this section we compare the results obtained in the previous models of price regulation with the allocative and efficiency effects of sliding scales regulatory schemes (i.e. profit sharing regulatory schemes). The reason for this comparison is the evident parallelism between flexible-cap regulation and sliding scales. In the following section, we will briefly examine the literature on sliding scales and then introduce a model (Lyon, 1996) which studies the effects of sliding scales on incentives to innovate.

The recent practice of incentive regulation is moving, especially in the US, towards the use of more varied forms of price regulation than simple price caps (for a general discussion, see Crew and Kleindofer, 1996). For instance, in 1991, the US Federal Communications Commission (FCC) introduced a price cap for the interstate access charges to be paid by local exchange carriers and successively revised those schemes to introduce some form of profit sharing[4]. Moreover, more than half of the states in the United States have adopted regulatory schemes which involve profit sharing (on this point, see Greenstein, McMaster and Spiller (1995)). However, the growing application of profit sharing (or sliding scales) regulatory schemes in practice has not yet resulted in a corresponding interest at the theoretical level (see Breatigam and Panzar (1993, p.197)).

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[4] For a discussion of the FCC regulatory schemes, see Sappington and Weisman (1996).

In fact, the literature on profit sharing regulatory schemes is not abundant. From an empirical perspective, Greenstein et al.(1995) examine the effects of state regulators' regulatory plans on investment decisions of local telephone companies; however, this analysis deals only with productive efficiency, so it does not provide clarification about the welfare effects of profit sharing plans. More work is available for a theoretical analysis of the properties of profit sharing schemes. Sappington and Sibley (1992) discuss the investment choices of a regulated firm, comparing price cap with regulatory schemes which present some examples of profit sharing. They find that the introduction of profit sharing can be welfare improving when investments are observable by the regulator (the case with unobservable investments is ambiguous). Gasmi et al (1994), following Schmalensee's proposal (1989), use simulation techniques to discuss and compare various regulatory regimes, including Schmalensee's family of (linear) 'good' regulatory regimes, a price cap scheme with downward flexibility, and a regime which mixes features of price cap schemes with profit sharing. In an adverse selection framework with unobservable investments, they find that profit sharing mechanisms can improve over price caps in the sense that they yield levels of welfare comparable to optimal regulation levels. Lyon (1995) shows that profit sharing regulation can induce the efficient choice relative to the introduction of a new and more efficient technology with lower expected costs but higher variance than the existing technology. Lyon and Huang (1996) discuss the incentives to adopt a new technology for a regulated firm (under a profit sharing scheme) competing with an unregulated firm. They find that, depending on the possibility of imitation, the rate of innovation at the industry level can be positively influenced by adjusting the share of profits accruing to the regulated firm.

The paper which is more interesting for our discussion is Lyon (1996). He studies a model, similar to those presented in the previous section, to examine the effects of simple linear price regulatory schemes on the incentives to innovate. Moreover, he discusses the welfare implications of those schemes for social welfare. In particular, he studies a sliding scale regulatory scheme, based on the introduction of a 'deadband' for the regulated firm's profits and of some profit sharing.

The basic price mechanism is simple. An initial price is set less or equal to the initial (observed) constant marginal cost level. This price remains unchanged if the profits of the firm remain in an interval (the deadband) defined by the regulator (this deadband can be influenced by the lobbying activities of consumers and by the regulated firm, not to mention the political pressure on the regulatory agency). If profits fall outside the deadband, they are shared between the firm and the rate payers, according to sharing parameters s_L and s_U (for profits below and above the band, respectively). Since Lyon assumes that the regulator cannot make lump-sum transfers to the firm, profits can be modified only by adjustments of the output price. In order to illustrate the relationship between price and costs, the cost levels corresponding to the lower and upper bound of profits can be defined as c_L and c_U, respectively. This relationship can be illustrated in figure 2. The similarity between this sliding scale mechanism and that of flexible-cap regulation is immediate.

With regard to cost reducing effort, Lyon shows that the firm increases its effort when it can appropriate a greater share of the gains from innovation. This happens when the upper (lower) bound on profits is raised (reduced) or when the firm's shares of benefits are increased. This implies a possible trade-off from a social welfare point of view, since greater shares of profits imply higher prices for consumers. The main result of the paper is the fact that, relative to price cap regulation (defined as a fixed price ceiling, irrespective of cost realisations), welfare can always be increased through small changes in the sharing parameters s_L and s_U, which jointly leave expected profits of the regulated firm unchanged. The intuition is that, starting from a price cap regulation in which there is no sharing, the introduction of sharing produces a first-order allocative gain but only a second-order effect in terms of reduced incentives for the firm[5].

[Insert figure 2 about here]

The fact that Lyon is able to prove (albeit without a general functional formulation) that profit sharing schemes can be superior, in terms of welfare, to price cap regulation, is interesting for the discussion of the welfare effects of the flexible cap presented in the previous section. There, we were not able to sign a priori the effect of a flexible cap on social welfare. One possible explanation of this difference rests in the definition of price cap used by Lyon. Since the firm is not reimbursed under his definition of price cap, for bad cost realisations, a sliding scale, which guarantees unchanged profits compared to a price cap, can induce allocative gain superior to the reduction in incentives. So, Lyon's result cannot be considered a definitive assessment of the relative merits of these alternative schemes.

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[5] Lyon presents numerical simulations to evaluate the magnitude of the welfare gains corresponding to a profit sharing scheme.

7. Concluding remarks

In this paper we have discussed the effects of alternative price regulation schemes on the incentives of a regulated firm to innovate, and we have discussed both price cap regulatory schemes and sliding scales (or profit sharing) schemes. Since we were not able to obtain clear cut results, in this concluding section we will try and briefly tie up some of the issues which we have discussed, offering some comments on possible developments of this work.

The choice of simple linear price regulation is motivated by the interest in evaluating regimes which could be encountered in the practice of regulation. However, we have not abandoned the idea of ranking those different price schemes in terms of incentives to innovate and of social welfare. In other terms, it would be interesting to be able to create a classification of the most appropriate regulatory regime in a second-best world of incentive regulation. A related point refers to the fact that both flexible cap and sliding scale regimes are characterised by more instruments than a simple price cap scheme (at least one more instrument). Since instruments can be costly to administer by a regulatory agency, one should also be able to assess the relative advantages of different regimes in terms of complexity.

The discussion in this paper has focused on the effects of price regulation for non-drastic innovation. If we also considered drastic innovations, the comparison between the different regimes could possibly change quite substantially. In that case, a firm may gain ‘excessive’ profits under a price cap regime, since it would possibly be able to set its monopoly price. If the distribution function of cost realisations is such that low cost levels have a sufficiently high probability of occurrence, then a downward flexible cap could ensure allocative gains and thus be welfare improving.

Finally, all this discussion has been presented in a static regulatory framework. However, innovation is typically an ongoing process. Thus, the comparison between flexible cap and traditional price cap regimes could also be reinterpreted, in a dynamic sense, as an example of the discussion about the relative merits of rules versus flexibility in regulatory systems. This topic is too vast to be taken up now, but a better understanding of the dynamic implications of price regulation for technological advance is obviously needed for ‘good’ regulatory regimes, as well.

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PRICE REGULATION AND INCENTIVES TO INNOVATE:

FIXED VS. FLEXIBLE RULES (*)

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SUMMARY

Since the seminal works of Schumpeter (1937) and Arrow (1962), economists have recognised that the innovation process is crucially dependent on the strategic environment in which firms operate and on the institutional arrangements which govern the appropriability of economic returns from innovation In this paper we focus on one particular aspect of the relationship between market structure and innovation, that is the effect of regulation on the incentives to innovate of a regulated monopolistic firm. More precisely, we discuss the influence of price regulation on the economic incentives to undertake costly R&D effort to discover a new technology.

After a discussion of positive approaches to regulation and their relevance for the policy debate about the relationship between innovative activity and regulation, the paper develops the analysis of different price regulatory schemes in terms of incentives to undertake R&D effort, comparing a traditional price cap scheme with a downward flexible price-cap scheme. The welfare analysis of these schemes and a discussion of their relative merits shows that a welfare ranking of the alternative forms of regulations is crucially dependent on the properties of the cost reduction distribution function. Finally, it is shown that the incentives effects induced by a flexible price-cap bear some similarities with the incentives to innovate resulting from the so-called ‘sliding scales’ regulatory schemes.

KEYWORDS: REGULATION, INNOVATION, PRICE CAP, FLEXIBILITY

JEL: L10, L51, O31

NON TECHNICAL SUMMARY

Economists and policy-makers have argued that the innovation process is crucially dependent on the strategic environment in which firms operate and on the institutional arrangements which govern the appropriability of economic returns from innovation. This paper discusses the effects of regulation on the incentives to innovate of a regulated monopolistic firm. More precisely, it studies the influence of price regulation on the economic incentives to undertake costly R&D investments to discover a new technology.

The influence of price regulation on the innovative activity of regulated firms is one of the main issues to be tackled in assessing the advantages of alternative forms of regulation. In particular, the UK privatisation and regulation experiences have been particularly important in bringing to the attention of industrial economists and policy-makers the relevance of price regulation as a tool for fostering innovative activity and efficiency improvements Following a policy perspective, the paper examines alternative schemes of price regulation and their effects on the incentives for a regulated monopoly to innovate. In this respect, we discuss whether some observed schemes of price regulation can be evaluated, from an economic theory viewpoint, to be beneficial to social welfare through the improvement of productive efficiency in regulated industries.

After a general discussion of current forms of price regulation and their relevance for the policy debate about the relationship between innovative activity and regulation, the paper is devoted to a comparative analysis of price regulatory schemes in terms of incentives to undertake R&D investments to improve the technology (i.e. lower costs). Clearly, since the innovation process is typically uncertain, the regulatory schemes will have to ensure positive expected profits for the regulated firm. Two different schemes are presented: a traditional price cap scheme, that is a price ceiling which induces the monopolist to invest in R&D in order to reap the benefits of cost reduction, and a downward flexible price-cap scheme, which allows the monopolist a lower price for low cost realisation. The welfare analysis of these schemes and a discussion of their relative merits show that the ranking of the different schemes is crucially dependent on the properties of the cost-reduction innovation process and thus the analysis points to the necessity of an empirical evaluation of the efficacy of R&D investments in terms of different cost-reductions obtained . The relevance of this discussion for current systems of regulation is witnessed by the fact that the properties and the incentives for innovation of a flexible price-cap bear many similarities with those obtained using ‘profit-sharing’ regulatory schemes. These types of schemes involve some sort of sharing between firms and consumers of the profits obtained by the regulated firms, and they are implemented, if the regulator cannot make transfer to the firm, by price regulation. It is interesting to note that these schemes are becoming more popular in practice and that the US Federal Communication Commission is moving towards some form of profit sharing for the regulation of access prices in the domestic market.

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