Voluntary Spillovers in Innovation and the Optimal Degree of Knowledge Excludability: A Simple Proposal

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1. INTRODUCTION

As Levin et al (1987) highlight to have the incentive to undertake R&D, firms must be able to appropriate returns sufficient to make the investment worthwhile. From this point of view, the central issue in the economics of innovation is how inventors manage their *knowledge* to create profits. In other words, the *core matter of research should be the endogenous determination of both investments in the creation of new innovative knowledge and entrepreneurial efforts to enhance the appropriability conditions of innovators.*

Although some exceptions, most of the theoretical innovation literature has focused mainly on the two following related set of issues. Firstly, many efforts have been devoted to characterize the *optimal amount of investment in R&D under different appropriability conditions.* In this direction of research, the appropriability degree of inventors and the technological leakages between firms are considered exogenously given and outside of some manipulation possibilities by entrepreneurs.. The basic *patent race* literature emphasizes how *appropriability conditions* are determined by the legal system of intellectual property rights and technological conditions. Therefore, little room is given to inventors to enhance their profits.

Secondly, the optimal design of a system of intellectual property rights (IPR) has attracted considerable amount of research. Broadly understood, the public policy with respect to innovation needs to deal with a delicate set of issues. Essentially, the creation and organization of new markets for the innovated commodities require the "protection" of the innovator's rights over their inventions. The enforcement of these rights is essential to reward those successful innovators and hence in providing them with the (ex-ante) incentives to invest in and encourage research and development. However depending on the market structure, most of the time, the rights conferred to the innovators endow them with enough market power to create economic distortions in their attempts of appropriating the surplus generated by their innovations.

Thus, in the patent design literature (Gilbert and Shapiro, 1990; Klemperer, 1990 and Green and Scotchmer 1995, among others) the debate is concentrated in how to structure the rewards to innovators. In these articles, given the reward that the patent should confer, the discussion is centered around the optimal *length* and *breadth* of the patent to achieve the sought reward. The results in this literature, which naturally differ according to the assumptions of each model, in general highlight the fundamental trade-off between incentives to promote R&D and the potential social costs created by the patent policy. For example, in Gilbert and Shapiro (1990) a set of sufficient conditions are provided to show that infinitely-lived patents are optimal; a result that is ultimately based on the assumption that enlarging the *breadth* of the patent is increasingly costly in terms of social welfare due to the monopoly power granted to the innovators. But although all of these papers concentrate on the important matter of optimal patent design, the fundamental issue of how much the reward to potential innovators should be is actually hidden. Thus, the optimal patent-design literature taken as given the reward patents should confer disregards one of the fundamental issues in the relation between property rights and efficiency. Again, nothing is said about the actions that inventors could take to improve their profit positions.

Also, in the empirical literature of innovation the issue of appropriation and incentives plays a central role. For example, Mansfield E. (1985) documents the speed at which various kinds of technological information leak out to rival firms. According to the author *"...for both processes and products, the odds are better than 50-50 that a development decision will leak out in less than 18 months. If it takes about three years or more before a major new product or process is developed and commercialized (which is fairly typical in many industries) this means that there is a better-than-even chance that the decision will leak out before the innovation project is half completed".*

In Levin et al. (1987) and Cohen, Nelson and Walsh (2000) the results of an inquiry into the appropriability conditions in more than one hundred manufacturing industries are carefully described. Their findings suggest that inventors do not consider patents as the most effective mechanism to protect their innovative knowledge. In fact the easy of inventing around a patent and the amount of information disclosed in a patent are two of the main drawbacks of the patent mechanism that might contribute to understand their findings.

But also, *they document that many potentially profitable innovations do not even qualify for patent protection*. It is in this case in which the issue of appropriability becomes even more transparent. *How the potential rewards of this innovative knowledge could be appropriated?. According to the authors, inventors resort to a careful mixture of secrecy and publication of their innovative findings. This suggests that instead of being harmful informational leakages might in fact enhance the appropriability conditions of inventors*. This is also in some sense confirmed by Von Hippel (1987) in his study of informal know-how trading between rivals. In the same way, Von Hippel et al. (2000) explains that *"...defying conventional wisdom on the negative effects of uncompensated spillovers, innovative users also often openly reveal their innovations to all users and manufacturers"*.

All of these evidence seems to imply that some current theoretical models of IPR leave opened to further research many important questions and issues about how appropriability conditions and informational spillovers are in fact determined. In this proposal, we explore the incentives that inventors might have to disclose useful innovative knowledge to their competitors when deciding their appropriability strategies. We develop a simple setting that might be a first step in modeling the findings of Cohen, Nelson and Walsh (2000) that in order to appropriate the fruits of many innovations -that do not qualify for patent protection- inventors resort to a delicate balance between secrecy and public revealing of their knowledge. The rest of the paper is organized as follow. In section 2, we briefly review the common structure models of innovation races and their main results with respect to appropriability conditions and R&D investments. Finally, in section 3, we present our proposal.

2. INCENTIVES IN R&D AND IPR

The central issue that surrounds the whole topic of the economics of innovation is the challenge faced by potential innovators in trying to appropriate the returns from their investments. Consistent with this central feature, many attempts have been done in the economic literature of innovation to characterize the optimal amount of investment in R&D *under different appropriability conditions.* Presumably, Arrow (1962) was the first to address the issue of the incentives to innovate under different market structures assuming that innovators would be protected by property rights (patents) of unlimited duration. Using an example of a process innovation and isolating the "pure" incentives to innovate (i.e. he did not consider strategic considerations between innovating firms) Arrow (1962) concluded that in both cases, monopoly and price-taking competition, innovators are not able to fully appropriate the social benefits of their innovations and hence underinvestment in R&D is an undesired feature of the market mechanism. This result is based on the following observations. First, the monopoly underinvest in R&D because a fraction of its cost improvements leaks out to consumers through lower prices. Second, under ex-ante competition, the innovator becomes a monopoly and she can charge a price at least equal to the old marginal cost (i.e. the pre-innovation marginal cost) which is higher than what would be the ex-post innovation competitive price (i.e. the post-innovation marginal cost). Third, the monopoly invest less than the representative competitive firm because the profit incentives (i.e. the difference between post-innovation profits and existing profits) are higher for a "competitive" firm.

However, the most interesting point of this analysis rest on the fact that even with perfect patent protection the problem of appropriating the social benefits of innovative activities arises. Hence, a first and useful distinction has to be made between potential appropriation failures due to **pecuniary externalities** imposed by the innovators -the problem identified by Arrow- and those failures due to **limited intellectual property rights**.

The problems of appropriability and the role of IPR has also been extensively studied in the economic literature. The following example provides some flavor of the relationship between IPR, technological spillovers and the efficiency of the innovation process.

Example: The Innovation Race and IPR

Consider a duopolistic industry, in which each firm can spend 1 and only 1 unit of R&D to discover a new commodity or process with social value V. The cost of this indivisible unit of R&D is C and if only 1 firm incurs that cost, the probability of discovery is p. We will assume that the expected social value of investing one unit of R&D is positive:

$$G_1 = pV - C > 0 \tag{1}$$

To avoid the appropriation problems due to pecuniary externalities, let us assume that iff imitation is not possible, the innovator would get the full social value of the innovation. Also, we assume that the innovation can be invented around freely by the other firm. If imitation is possible, we assume that each firm (i.e. both the innovator and the potential imitator) would get a fraction $\beta < \frac{1}{2}$ of V. Hence if imitation is possible, the expected payoff to R&D is:

$$\beta pV - C \tag{2}$$

If (2) is negative, then firms would not invest in R&D, even when it is socially profitable to do so. However **if IPR make imitation unfeasible, private incentives would be aligned with the social ones.**

Now, assume that if both firms undertake R&D, the probability of firm 1 making a discovery is statistically independent of the probability of success of firm 2. Therefore, the total gains of having two firms participating in the race is:

$$G_2 = (2p - p^2)V - 2C \tag{3}$$

And the marginal product of each firm is:

$$MP_i = G_2 - G_1 = (p - p^2)V - C \tag{4}$$

In the case of no IPR, if both firms invest in R&D, their expected payoffs are equal to:

$$\pi_i^2 = \beta(2p - p^2)V - C \;\; i = 1, 2 \tag{5}$$

But if only one firm invest in R&D, the payoff to innovation and imitation are respectively:

$$\begin{aligned} \pi_{innovator} &= \beta p V - C \\ \pi_{imitator} &= \beta p V \end{aligned} \tag{6}$$

The following proposition shows that even when $\pi_{innovator} > 0$, incentives to invest in R&D may be insufficient without IPR.

Proposition 1: Let $\pi_{innovator} > 0$. Assume that $MP_i > 0$, that $\frac{C}{\beta} > V(p - p^2)$ and, for simplicity, that both firms simultaneously decide whether or not to invest in R&D. In this case, the total gains are maximized when both firms invest in R&D, but there can NOT be a Nash equilibrium in which both firms undertake R&D.

This underinvestment result clearly depends on (i) the value of the innovation, V; (ii) technological factors, C and p; and (iii) the degree of appropriability β. *In fact what is important to determine the underinvestment result is the ratio of the innovation costs, C, with respect to the degree of appropriability β. A low β due to limited IPR does not necessarily imply that the underinvestment result will prevail, if the innovation costs are small enough.*

However if patent protection is provided, the payoff to each firm of participating in the race -conditional on the other participating- is:

$$\pi_i^{2IPR} = \frac{1}{2}(2p - p^2)V - C \;\; i = 1, 2 \tag{7}$$

Here it is assumed that if there is a tie between the firms, only one obtains the patent and that each one of them has an equal chance of this. Obviously, in this case $\pi_{imitator} = 0$. Using (4) and (7), we have that:

$$\pi_i^{2IPR} = MP_i + \frac{1}{2}(p^2 V) \tag{8}$$

Expression (8) drives the results summarized in proposition 2.

Proposition 2: If $MP_i > 0$, then under the prospect of patent protection both firms will take the right decision in equilibrium. But if $(p - p^2) < \frac{C}{V} < (p - \frac{1}{2}p^2)$, then we have both $MP_i < 0$ and $\pi_i^{2IPR} > 0$, which imply that too much investment in R&D.

These results show that when IPR leads to winner takes all results, one should expect at least as much R&D investment as in either (a) a regime without patent protection or (b) the social optimum (Bessen, J and Maskin E., 2000)

In this example of a patent race, *knowledge spillovers* occurs after the race ends *(imitation)* and they are entirely determined by the system of IPR. In other words, in order to study the properties of investment in R&D, a wide kind of patent race models consider *information transmission between rivals as an ex-post and exogenously determined phenomenon.*

How the possibility of *interim knowledge spillovers* affect the incentives to innovate has also been addressed in Reinganum (1981). Using a dynamic racing model, the author compares the investment rates of Nash rivals with respect to those of R&D cooperation. The main result is that in a duopoly with no spillovers in racing, Nash rivals could be expected to innovate at an earlier date (as a result of having greater investment rates) than cooperative firms; but with high *interim spillovers*, one obtains the opposite tendencies.

Spence (1984) and d'Aspremont and Jacquemin (1988) presented influential strategic investment analysis in duopoly models to study the effect of *interim knowledge spillovers*. The common structure of these models is as follows. In the first stage, firms investments in R&D lead deterministically to cost reductions (process innovations). In the second stage, they compete in the product market, generally, á la Cournot.

The possibility of *knowledge spillovers* is introduced through a spillover parameter $\beta \in [0, 1]$. Using a simple example, d'Aspremont and Jacquemin (1988) compare the efficiency -through the level of R&D expenditures and the total equilibrium output in the second stage- of three different mechanisms or innovation games: (a) **Rivalry**: competition in both stages; (b) **Partial Collusion**: cooperation in R&D efforts and competition in the second stage; and (c) **Full Collusion**: cooperation in both stages.

The efficient solution requires not only more production but also a higher level of R&D than what the authors obtained with any of the previous innovation mechanisms. But when these mechanisms are compared, the conclusions obtained depend critically on the level of β. In general, it is shown that there exists a critical value for the spillover parameter, β^*, such that for $\beta > \beta^*$ **Partial Collusion** is superior to **Rivalry**, otherwise the reverse is true. Finally, for large spillovers -$\beta > \beta^*$- the amount of research which is closest to the optimum is the one achieved by **Full Collusion**, followed by the investments in the case of **Partial Collusion**.

So in general, this literature has been extensively devoted to the understanding about the connections between *appropriability conditions, technological spillovers and the efficiency of the investment process in R&D*. With this purpose, information transmission between rivals is considered *exogenous* and the distinction between *interim and ex-post knowledge spillovers* is rarely distinguished. *In all of these models, the appropriability enviroment of the inventors is almost completely determined by technological and legal conditions, often summarized in the system of IPR*. Whatever the degree of protection offered by IPR on the information generated by the innovation process, *the owners of potentially proprietary information neither do not spend any amount of private resources to increase their profits nor they tried to manipulate the flows of information to and from their rivals.*

Also, these type of models assume that patent protection is almost the unique mechanism of protecting intellectual assets. However, several issues are completely absent.

First, in many cases innovative and potentially commercially valuable knowledge does not qualify for patent protection: patentability requires "novelty" and "nonobviousness". *In these cases, owners of proprietary information may resort to secrecy as an alternative appropriation mechanism.* Second, patents require that useful technical information be publicly disseminated. This informational property of patents is also completely overlooked in the above models. Third, in many occasions patents are invalidated or vitiated in subsequent legal challenges. Hence, patents sometimes provide only limited and uncertain exclusivity to the commercial exploitation of innovative knowledge.

All of these comments point out to the importance of understanding how owners of commercially valuable proprietary information may resort to some other alternatives and private mechanisms to enhance their appropriability conditions. Potentially, the simultaneous understanding of both (i) firms' investments to generate innovative knowledge, and (ii) inventors' expenditures and maneuvers to improve the appropriability conditions of their innovative knowledge, might shed additional light on the relationships between investment in R&D, legal property rights and the efficiency of the innovation process. However, in the rest of this paper we concentrate more closely on those maneuvers that innovators might resort to in their attempts to improve their appropriability conditions and we make an effort to link these actions to the issue of knowledge spillovers between rivals.

PROPOSAL: DISCLOSING INNOVATIVE KNOWLEDGE UNDER THE SHADOW OF COMPETITOR'S PATENTING ACTIVITIES.

1. Motivation

In a recent paper Cohen, Nelson and Walsh (2000) examine what mechanisms are used by manufacturing firms to protect their intellectual assets. They found that..*"although patents may have increased in importance among large firms, they are still not one of the major mechanisms in most industries when the views of all firms are considered. We also find the importance of secrecy to have increased dramatically..."*. In their survey, firms were asked which reasons contributed to the decision not to apply for a patent on the most recent invention which they decided not to patent. Among several ones, their results suggest that the **easy of inventing around a patent**, **the amount of information disclosed in a patent, and the difficulty of demonstrating the novelty of potentially profitable commercially innovative knowledge** are the ones that scored highest.

Although *secrecy* is used frequently by owners of proprietary knowledge, Cohen, Nelson and Walsh (2000) also found evidence that some fraction of not patented innovative information is systematically published or freely disseminated into the public domain. Common forms of voluntary disclosure of information are for example conference presentations.

Liebeskind J. (2000) have also found similar results to those of Cohen. et al (2000). The former paper, based on interviews and obervational data from different firms, contains information about the choices of innovators between legally defined property rights (de jure) and informal (de facto) property rights. The case studies confirmed that many different types of innovative knowledge do not qualify for legal property rights -patent or copyright protection-. Also, the author documents that *"...occasionally, however, the firms we studied elected to contribute certain items of knowledge to the commons by publishing that information without prior legal registration of their rights"*.

All of this evidence suggest that in fact *information communication* between rivals is far from being exogenous. To the contrary, the degree of knowledge spillovers seems to be a crucial aspect of the appropriability strategies of innovators. Hence, some obvious questions arise: Why do firms transmit useful information to their rival?

How do these knowledge spillovers contribute to improve the appropriability degree of firms? What are the economic, legal and technological determinants of knowledge flows?

2. Overview of the Argument

The crucial insight to understand why owners of (valuable but non-patentable) information might freely disseminate knowledge that could be used by their rivals relies on the fact that s*trategic knowledge disclosure by one firm could preempt the attempts of patenting similar commercially valuable knowledge by their competitors.*

The patent system confers to inventors the right to exclude others in the use of the patented knowledge. However for inventors to have access to this right, the knowledge to be patented must satisfy the legal requirements of "novelty" and "nonobviousness". These requirements are hard to interpret and there is room for discretion in determining whether a new technology should qualify or not for patent protection. But in general, the probability that a new piece of knowledge be patented depends on the information contained in previous patents and also of the amount of similar public and common knowledge.

Therefore, as we suggested, owners of innovative non-patentable information might manipulate their competitors' legal possibilities of obtaining exclusive rights by strategically disclosing their innovative knowledge. Hence, even though non-patentable valuable knowledge could be protected by *secrecy*, t*heir owners might choose to freely reveal at least part of it, when they are uncertain about the legal possibilities of their rivals in obtaining IPR -patent protection- for similar pieces of knowledge.*

It should be noticed that our arguments fits in both cases in which knowledge could be protected through either trade secrets -legal rights- or informal secrecy -de facto rights-. If knowledge were protected by trade secret law, in the US, subsequent inventors' patents would be consider valid by the courts in certain cases and, most important for us, first inventors would not have prior user rights (Denicolo, V and Franzoni, L., 2000).

But the decision of transmitting innovative knowledge to competitors has other two important dimensions that need careful understanding. In first place, the kind of *innovative knowledge* we are referring to shares the features of a *public good*. On one hand, it is an *excludable public good*, because competitors can be prevented from using it, if kept secret. On the other hand, knowledge is a *non-rival commodity*, because it can be used by several firms at the same time. It is this s*econd feature of knowledge that creates the main countervailing incentive toward full disclosure: the amount of transmitted information can freely be used by potential rivals.* Second, partial disclosure of knowledge is a signal of the amount of total knowledge owned by the innovator. How this signal affect profits depends on the nature of downstream competition between firms[1].

Summarizing, the whole argument has several important related components. In first place, when *innovative knowledge* does not qualify for patent protection, the owners of it could resort to secrecy to prevent the *excludable feature* of it. If all of the innovative knowledge were protected by secrecy, *excludability* would be complete and *informational spillovers* would be absent. Second, both the possibility that commercial exploitation of that knowledge be limited by similar subsequent patented innovations and the fact that protection by patents is granted only if the novelty requirement is satisfied imply that *information transmission might be used as a strategic weapon* to prevent being excluded in the use of innovative knowledge. In other words, the "acquisition" possibilities of IPR by one firm might be seen as summarized by a legal possibility set, that might be subject to manipulation by their rivals through

[1] The public good and signaling aspects of knowledge are also consider in innovation settings by Anton and Yao (1999 and 2000). The relationship of these papers to the idea proposed here is commented later.

appropriate information disclosures -*disclosures in the shadow of competitors' patenting activities*-. Third, the *non-rivalrous* aspect of knowledge creates a countervailing incentive to the disclosure effect analyzed above, by *enhancing the production possibilities of competitors*. Fourth, knowledge disclosures serve as *signals* about the total amount of innovative information owned by the firm and this *signal* affects profits in a way that critically depends on the nature of downstream competition.

When all of these elements are simultaneously considered, we hope it is possible to get valuable insights about how the *optimal degree of knowledge excludability* - or the spillover rate- is endogenously determined.

3. Towards a Formal Model

We might capture the fundamental tensions determining the optimal degree of *knowledge excludability* in a simple duopoly game with several stages. Suppose that two firms are trying to get an innovation. At this point, let say that it might be a product or process innovation, although the interpretation of a process innovation is somewhat easier. In the first stage, as a consequence of a probably not modeled R&D race, one of the players -the leader (L)- receives two pieces of private information. On one hand, L receives a signal about the cost of producing a given commodity. This signal is obtained from a distribution with cdf F and support $C = [c_l, c_h]$. The convention is that c_h represents the current cost of production in the industry. On the other hand, she receives an additional signal about the probability of patenting the innovation. We assume that this signal can take two extreme values: $\delta = 1$ with probability θ and $\delta = 0$ with probability $1 - \theta$. The interpretation is the following. If $\delta = 1$, the innovation qualifies for patent protection, otherwise excludability is only possible through secrecy. If $\delta = 1$, knowledge may be patented and the patent-holder is given the exclusive right to its use until a new and superior technology replace the old one. Hence for those leaders with $\delta = 1$, secrecy is an inferior choice when compared with patenting. The interesting analysis is for those leaders with a realization of $\delta = 0$. In the second stage, L has to decide how much knowledge to protect. For the moment, let us concentrate in those L with $\delta = 0$. Her decision is a function mapping cost realization to knowledge disclosures. Formally, the conditional spillover function is: $\sigma : [c_l, c_h] \to [c_l, c_h]$. This function must satisfied the *feasibility restriction* that if the leader's knowledge realization is c, then $\sigma(c) \geq c$. In the third stage, the other firm -the follower (F)- receives the same kind of private information about innovative knowledge as the leader in stage 1. The important challenge here is to model the strategic effect of information disclosure in stage 2 over the patenting possibilities of a F with $\delta = 1$.

Here, I am considering two alternatives.

(a) One way of doing this, it is just by assuming that the extent of knowledge disclosure, σ, weakly decreases the ex-ante patentability (δ) of the knowledge owned by F. In other words, if $F's$ signal is $\delta = 1$, then the ex-post probability of patenting -or the IPR possibility set of F- is

$$\delta^{EXP} : \sigma(C) \to [0, 1]$$

where $\delta^{EXP}(\sigma(c_h)) = 1$ and $\delta^{EXP}(\sigma(c_*)) = 0$. The determination of c_* is not explained in this modeling choice and it would depend on the legal features of the patent system -one possibility would be $c_* = c_l$-. Under this interpretation, the ability of L to manipulate the patenting possibilities of F depends on both *the amount of knowledge owned* and *the amount of it that is left unprotected.*

(b) In this formulation, the IPR possibility set of the F is:

$$\delta^{EXP} : [\sigma(c) - c_f] \to [0, 1]$$

where $\delta^{EXP}(\sigma(c) - c_f)$ is an increasing function such that for $\rho = \sigma(c) - c_f < 0$, $0 \leq \delta^{EXP}(\rho) \leq 1$ and for $\rho = \sigma(c) - c_f \geq 0$, $\delta^{EXP} = 1$. Similarly to the previous case, we might define a $\rho_* < 0$ such that $\delta^{EXP}(\rho_*) = 0$. Under this formulation, the ability of L to manipulate the $F's$ IPR possibility set depends not only on *the amount of knowledge owned* and *the amount of it that is left unprotected, but also on the amount of knowledge owned by the* F.

Finally, in the fourth stage if F patented the innovation, a monopoly right is granted until a new and superior technology replaces the old one. Hence, although not explicitly modeled, the pace of the innovative activities and how rapidly new technologies substitute old ones determines the continuation payoffs of the players. If F did not obtain patent protection, then L and F compete in the product market. It is in this particular case that the *signalling characteristic of knowledge* could play a role depending on the type of equilibrium analyzed. If the equilibrium were *separating*, then the game would be one of one-side asymmetric information, in which the type of L would be inferred by F. In this case, this signal could potentially benefit or not the leader according to the type of downstream competition between the firms. In the *Cournot (Bertrand)* case, where the actions are *strategic substitutes (complements)*, the L would be benefited (hurt) (Okuno-Fujiwara et al, 1990).

4. Related Literature

The relevant aspects of strategic information disclosure analyzed in this proposal are similar to those of Anton and Yao (1999 and 2000), Battacharya and Ritter (1983), Horstmann, Mac Donald and Slivinski (1985), Okuno-Fujiwara et al. (1990) and Scotchmer and Green (1990). In Anton and Yao (1999 and 2000), it is analyzed how much information is disclosed by innovators when patenting their innovative knowledge. They analyze knowledge disclosures through patenting activities when the exclusivity provided by patents is limited. Hence, they argue that an inventor is less likely to disclose the full extent of its innovation because of the possibility that either patents be invalidated in courts (Anton and Yao, 1999) or innovations be imitated with "legal success" by potential imitators (Anton and Yao, 2000). The main force in their model that pushes innovators to disclose part of their knowledge through patent claims is the signal that the patent sends about a patent-holder's competitively-relevant private knowledge. Hence, it is easy to understand both their focus on *separating equilibria* -otherwise beliefs remain unchanged- and the *Cournot* nature of the potentially downstream competition.

Although in some aspects similar, our proposal has several different features. First, in their model the extent of the disclosure in the patent claim **does not** affect the probability of obtaining a patent, and as we said the incentives to disclose knowledge are crucially determined by the nature of downstream competition. Differently, in our case *L transmit innovative knowledge not to exclude others of its use -as in the case of patenting activities- but rather as a starategic weapon to avoid of being subsequently excluded by the patenting activities of others*. Hence the incentives to disclose are completely different and the signaling aspect of knowledge in our case plays, in principle, a secondary role. Second, our proposal highlights not only the public good aspect of knowledge but also its peculiar feature -similar to a real externality- of being able -if correctly managed- of changing the IPR set of rivals. Finally, different to their papers, *the type of knowledge we are interested on does not qualify for patent protection and hence private efforts to appropriate it must be done resorting to secrecy. The legal option of patenting it is not opened to L.*

Battacharya and Ritter (1983) considered a model in which partial disclosure of technical information reduces the cost of capital to a firm competing in a R&D race, but generates additional entry into that race. In Horstmann, Mac Donald and Slivinski (1985), an inventor must choose whether to patent and the follower chooses either to stay out, imitate (without risk of being punished by the legal system) or duplicate the technology (only feasible under no patent). The innovator has private information about the payoffs of the follower for each of these actions. Hence, the issue is not about how much knowledge is disclosed but rather how the patenting activity signals the profitability of each of the actions opened to the competitor. To understand the basic idea in their papers, it is worth noticing that if the innovator chooses to patent, then the follower stays out. The basic reason is that a patent signals that imitation is not profitable.

In Okuno-Fujiwara et al. (1990), the issue of strategic information revelation is considered in asymmetric information games when the agents have the possibility of revealing their information to other agents prior to playing the game. The main message of that paper is that to the extent that such communications are believed by the other agents, the priors of the other agents will change and the payoffs of the communicating player might increased. Notice the similarities with the strategic incentive to disclose knowledge in Anton and Yao (1999 and 2000). I*n our story, the change in beliefs is of secondary importance in the incentives to disclose information.* Also in our proposal, as in Okuno-Fujiwara et al. (1990) and Anton and Yao (1999 and 2000), information disclosures are constrained to be truthful.

Finally, Scotchmer and Green (1990) focus on the impact of IPR -novelty and nonobviousness- on both the incentives to innovate and to disclose useful innovative knowledge. In their case, partial disclosure is not allowed, and knowledge could be interpreted as an indivisible commodity.