9th ICABR International Conference on Agricultural Biotechnology: Ten years later

Ravello (Italy), July 6 to July 10, 2005

Trade secrets, Patents and Options

by

Odin K. Knudsen and Pasquale L. Scandizzo

ABSTRACT

This paper examines the problem of protecting property rights under dynamic uncertainty. The problem is cast in the framework of a multiple option nexus characterizing the process of R&D investment, innovation, imitation and conflict. The innovator is assumed to hold an option to invest in R&D, whose uncertain results are threatened by imitators, who hold an option to invest to appropriate some of the possible fruits of the R&D project, should this succeed. The innovator can invest in trade secrecy to protect her invention. Alternatively, she has an option to seek legal action against the imitator, should the latter exercise her own option to carry on the imitation process. The value of the legal action depends on the cogency of the intellectual property rule and on the legal costs to recover damages, i.e. the effectiveness of the liability rule protecting intellectual property. Both the cogency of the intellectual property law and the effectiveness of the liability rule are an option held by society, which has to balance the need to protect innovation and to ensure that, once realized, innovation is spread through the economy at a reasonable speed. The paper finds that both the innovator and the imitator are motivated to reach an equilibrium on the basis of their net gains from their respective actions minus the value of the contingent threat held by the other agent. Government intervention should be limited to "level the field", i.e. equalize the conditions under which innovators and imitators operate.

I. Introduction

Since Calabresi ad Melamed seminal article n 1972, liability rules are said to create positions similar to financial calls and puts whereby the entitlement is forcedly transferred from the entitlement older to the injurer trough payment a judge given damage award working as a strike price. - "*If virtually all projects have embedded* *options, only an approach such as (real options) can be appropriate. Ignoring the options is likely to lead to serious undervaluation*". (Klock)[1]. This does not mean that financial options are really there since a contract to purchase it is absent.

Can we assimilate the legal purchase of any financial option contract to the creation of these incentive mechanisms? Are the rights descending from a financial option contract really the same as those held by potential injurers? Is the position of a potential injurer a real right in the end, namely a relevant interest that the legislator has risen to the dignity of an enforceable right – like for any other real right in the system? Or is it not a privilege or some sort of lower dignity juridical position?

At first sight the position can only in theory be assimilated to *calls* and *puts option rights*. "A financial option contract provides its owner with the opportunity, but not the obligation, to buy or sell some other underlying financial instrument, such as a bond, stock, index, or specified amount of foreign currency at a pre-specified currency exchange rate". (Huang 2000). [2]

Technically no real *call* nor *put* is bought through the incentive mechanism described above since otherwise we would see a contract signed and handed over to the injurer. Also, the injurer's call option is against every entitlement holder whereas a normal financial call option right only works against the contractual party who sold it.

As Ayres put it, quoted by Bar-Gill (Bar-Gill p. 1.nt. 1[3]) "*In Hohfeldian terms every privilege is an option to do some act and every power is the option to change some legal relation*" (Ayres forthcoming p. 5[4]). It was recently noticed that the only elements of Hohfeld's system that are relevant to the modern option analysis are those of his famous theory of juridical opposites and correlatives (Smith and

---

1 **Klock, Mark** (2004) "Financial Options, Real Options, and Legal Options: Opting to Exploit Ourselves and What We Can Do About It" in *Alabama Law Review*, volume 55 , issue 1 , p. 63-110).

2 Nor can we say that a liability option is equivalent to the "option" concept as it appears in two important spot in the Italian civil code.
Under Italian law, the term option is used to define a particular "option pact" (patto di opzione) (art. 1331) that is sometimes embedded in a contract. The pact is specifically intended by the parties to modify the way the contract is to be concluded. The usual conclusion pattern in both common law and civil law systems mandates that to the offeror's proposal the offeree's choice is to accept or refuse acceptance. The offeror however is free to withdraw his proposal until he hears from the offeree. By introducing an option pact this liberty is waived and the offeror remains subject to the proposal made. In other words the offeror gives away his right to revoke and confers upon the offeree the right to unilaterally decide whether to conclude the contract.
The term option also appears in the civil code to define (art. 2441) the "option right" to buy newly emitted securities that is assigned at the time of new securities issuances to current shareholders (prelazione). Such "option right" may be included in a sale agreement of financial securities with a fixed term. (art. 1532)

3 **Bar-Gill, Oren (2004)** "Pricing Legal Options: A Behavioral Perspective". [Sources: **1.** http://www.law.virginia.edu/home2002/pdf/olin/conf04/bar_gill.pdf. [Preliminary and Incomplete: August 23, 2004] M. Olin Conference on Real Options and the Law, October 1-2, 2004, www.law.virginia.edu/home2002/html/academics/olin/olin_conference04.htm - 36k.l **2.** http://www.law.umich.edu/CentersAndPrograms/olin/papers/Fall%202004/bargill.pdf [presented December 2, 2004 at The University Of Michigan Law School, The Law and Economics Workshop].

4 **Ayres, Ian (forthcoming 2005)**, "*Optional Law: Real Options in the Structure of Legal Entitlements*" (University of Chicago Press, Chicago, IL). 264 p.

Merrill)[5]. And in fact some fundamental work dealing with legal options today build upon this classification. [6] In the 1913 article Hohfeld[7] established that concept of a legal "right" (in the sense of a right-claim) must have its necessary correlative in the existence of a legal "duty" in someone else, be it in rem or in personam rights. "*By the same token, the opposite of a right is a no-right, whose correlative in turn is a privilege. All the various jural relations can theoretically be in rem or in personam; thus one could have in personam (Hohfeld's paucital) or in rem (Hohfeld's multital) rights, privileges, powers, immunities, no-rights, duties, disabilities, and liabilities, for 16 possibilities in all*".

The option analysis is a powerful tool to assess the true nature of legal positions and has been linked with real option analysis. "*Interestingly, however, the insights that might be gained from the options literature have not been widely transferred to other areas of law. The law is full of embedded options such as: the option to declare bankruptcy; the option to litigate; the option to waive rights; the option to use alternative dispute resolution; the option to abrogate a duty; and so forth. Many of these situations continue to be modeled purely as what* [the author] *calls primitive decisions, without recognition of the embedded options. But recognition of embedded options, the implicit exercise costs, the expiration dates, and the positive marginal value that increased uncertainty adds to options can enhance our understanding of these choices and suggest policy changes for mitigating inefficiencies in the law*"[8] . Other authors agree. "*Diverse set of legal doctrinal areas, including antitrust, bankruptcy, civil (including contract, tort and property laws) and criminal procedure, corporations, environmental regulation, jurisprudence, property, securities, and tax all involve the acquisition or granting of often hidden options. Examples of the breadth and scope of applying the real option perspective to law include realizing that corporate appraisal rights are real options, viewing civil procedure as regulating litigation options embedded in lawsuits, and characterizing the preservation of ecosystems and endangered species as real options*. **(Huang , 2000)** [9] For instance contact law creates a number of option the best known of which is the promisor's choice between performing or breaching a contractual provision and

---

5 **Smith, Henry E. and Merrill, Thomas W. (2001)** "The Property/Contract Interface". Paper presented at the John M. Olin Center For Law & Economics The University Of Michigan Law School, The Law and Economics Workshop March 15, 200. Available at: http://141.211.44.51/centersandprograms/olin/workshops.htm Draft 02/27/01)

[6] **Morris, Madeline (1993)** *The Structure of Entitlements*, 78 Cornell L. Rev. 822 (1993). In this article the author integrates Hohfeld's theory of jural correlatives with Calabresi & Melamed's theory of entitlements dated 1972.

[7] **Wesley Newcomb Hohfeld (1913)**, *Some Fundamental Legal Conceptions as Applied in Judicial Reasoning*, 23 Yale L.J. 16 (1913), reprinted in *Wesley Newcomb Hohfeld, Fundamental Legal Conceptions As Applied In Judicial Reasoning And Other Legal Essays* 23-64 (Walter Wheeler Cook, ed. 1923).

[8] **Mark Klock (2003)** "Financial options, real options, and legal options: opting to exploit ourselves and what we can do about it." 1. 55 Ala. L. Rev. 63 Alabama Law Review Fall 2003

[9] **Huang, Peter H. (2000)** Teaching Corporate Law From An Option Perspective, 34 *Ga. L. Rev. 571* (Georgia Law Review) Winter, 2000, Symposium Business Law Education Corporate Finance.

paying damages (Katz 2004[10] and Scott and Triantis 2004[11]). Civil law sometimes creates election of remedies: this also can be seen as a put option[12] (Bar Gilles 34) .

As an alternative to trade secrecy, patents represent a stronger protection of intellectual property rights. The objective of a patent system is to promote scientific discovery and development by granting innovators exclusive right over an invention. This right generates rewards to the patent holder through monopoly power over the use of the discovery or invention. To limit the excessive use of this monopoly, governments usually grant the patent for a fixed period, for example, 20 years as in the United States.

Much of the debate over patent policy has developed over the trade off between the dynamic benefits to innovation and research and development and the static losses associated with monopoly power granted through the patent. This debate is usually structured over two components of patent policy: length and breath. The length is the time granted by the government to the right to use the invention; the breath to the potential rewards or profits from the right to the patent. Gilbert and Shapiro (1988) analyze this structuring of patents and conclude that the optimal length of a patent is infinite. If this is the case, then patent policy should not be focussed on patent length but on the profits available to the holder of the patent. Patent breath would be adjusted to some fixed reward sufficient to induce a desirable rate of innovation. However, Klemperer (1990) and Gallini (1992) find under different assumptions on the nature of competition that finite length patents are optimal. Denicolo (1996) examines the race for patents using several examples on the nature of competition to explain the different results on optimal patent length and breath. He finds that optimality depends on the relationship between social welfare and the post-innovation profits. Reducing the breath of a patent leads to more competition in the product after the innovation, provided that there are not social costs associated with competition.

1. The Model

[10] **Katz Avery Wiener (March 2004)** “The Efficient Design of Option Contracts: Principles and Applications” C*olumbia Law and Economics Working Paper No. 248*

[11] **Scott, Robert E., and George G. Triantis (forthcoming 2004)**, "Embedded Options and the Case Against Compensation in Contract Law," *Columbia Law Review*, 104

12 Bar-Gill, Oren (2004)

Consider the problem of an entrepreneur, who has developed an innovation and is threatened by an imitator. The imitator may access the innovation by undergoing some investment costs. The innovator may in turn try to discourage imitation by undergoing herself some costs to protect her innovation through trade secrecy.

We assume that the net gain from the innovation is governed by a stochastic process of the geometric brownian motion variety:

(1) $$dy = \alpha y dt + \sigma y d\zeta$$

where y indicates the expected flow of the net gain, α and σ are, respectively a trend (the "drift") and a volatility parameter, t is time and $d\zeta$ is a random variable with zero mean and variance equal to dt. Under these conditions (Dixit and Pyndick, 1994), we can express the threat of the imitator as an option to appropriate a fraction of the income of the innovator and the trade secret rights of the latter in turn as an option to seek a preventive injunction and compensation for damages through the judicial system. More precisely, we can express the objective function U_N of the innovator as follows:

(2) $$U_N = \frac{y}{\delta} - C - By^{\beta_1},$$

where $\delta = r - \alpha$, r being the discount rate, C indicate the costs of protecting secrecy, β_1 is a parameter inversely related to volatility that can be determined as the positive root of the characteristic equation (Dixit and Pyndick, 1984):

$$\beta = \frac{1}{2} - \frac{(\rho - \delta)}{\sigma^2} \pm \sqrt{\left[\left(\frac{\rho - \delta}{\sigma^2}\right) - \frac{1}{2}\right]^2 + \frac{2\rho}{\sigma^2}}$$ and:

(3) $$By^{\beta_1} = \gamma \frac{y}{\delta} - K - \lambda C - Dy^{\beta_1} - S,$$

In expression (3), in turn γ is the share of the innovator's gains that the imitator threatens to appropriate, K are the imitator's discovery and imitation costs, λ is a measure of the effectiveness of the costs incurred by the innovator, Dy^{β_1} is the "option to sue" held by the innovator (defined below) and S the costs that the imitator would have to bear to convince her not to litigate in court. Notice that the strike price of the option to imitate is composed of three parts: (i) the investment cost K of the imitation project, (ii) the additional costs λC induced by the protection activities of the innovator, and (iii) the costs S that the imitator would have to bear as a consequence of the damage recovering attempts of the innovator.

(4) $Dy^{\beta_1} = \mu\gamma \frac{y}{\delta} - V - \theta S$

In expression (4), μ indicates the amount of damages that can be recovered by the innovator if she goes to court, V are the costs that she has to undergo if she does, and θ a measure of the effectiveness of the discouraging costs of the imitator. The costs V are a measure of the degree of legal protection accorded to innovation. If they are sufficiently low, they are equivalent to a property rule, that will enable the innovator to recover the entire value of the damages and stop the imitator from proceeding further. If they are sufficiently high, on the other hand, they will only act as a complement to the innovator's efforts to protect herself with trade secrecy and other private means.

Finally, we must consider the value of the option to invest in innovation:

(5) $Ay^{\beta_1} = \frac{y}{\delta} - I - C - By^{\beta_1}$

where I are the relevant R&D costs that the innovator faces.

The system in (2)- (5) expresses the problem of the possible conflict between innovator and imitator over trade secrecy as both a direct attempt, respectively, at protecting or copying the innovation and an indirect attempt at discouraging each other from contingent actions. Thus the value of the imitator's option to copy is both reduced by high trade secrecy measures and by the threat to sue on the part of the innovator. Similarly, the value of the innovator's option to innovate is reduced by high investment costs, and by the threat to imitate. The value of the innovator's option to sue, if copied, on the other hand, is also lower, the higher the costs of the judicial system and the more effective the dissuasion costs of the imitator.

2. The imitator's behavior under the threat of legal action

Consider first the problem of the innovator in case her product is copied and the trade secret broken .Equation (4) states the value matching condition, i.e. that the innovator's option to go to court will be exercised if its value matches the expected compensation to be granted net of the judicial costs plus any opportunity costs of off court settlement. In addition to this equation, the smooth pasting condition (Dixit and

Pyndick, p….) requires that the marginal value of the option equals its marginal cost for any additional increase in the value of the expected gain:

(6) $\beta_1 D y^{\beta_1 - 1} = \mu\gamma / \delta$

Putting together (4) and (6), we find the critical value y_M at which the option to sue will be exercised, the value of the constant D and the general expression for the option value:

(7) $\frac{y_M}{\delta} = \frac{y}{\mu\gamma\delta} \frac{\beta_1}{\beta_1 - 1}(V + \theta S)$

(8) $D y^{\beta_1} = \frac{\mu\gamma}{\delta\beta_1}[\frac{\delta}{\mu\gamma} \frac{\beta_1}{\beta_1 - 1}(V + \theta S)]^{1-\beta_1} y^{\beta_1}$

As expression (8) shows, the value of the option to go to court depends on how much the imitator is willing to spend to avoid the litigation (S), as well as on the innovator's willingness to be discouraged from the recourse to the judicial system, or to accept an out-of the court settlement (θ). More specifically, the imitator will aim to determine the value of costs S^* that maximize her expected gain after the imitation has been consumed:

(9) $S^* = \arg\max[U_m = \gamma \frac{y}{\delta} - K - \lambda C - D y^{\beta_1} - S]$

Substituting (8) into (9) , the first order condition to determine S^* is:

(10) $\frac{\partial U_m}{\partial S} = [\frac{\delta}{\mu\gamma} \frac{\beta_1}{\beta_1 - 1}(V + \theta S)]^{-\beta_1} y^{\beta_1} \theta - 1 = 0$

This condition defines a maximum, since the second derivative of U_m with respect to S is always ≥ 0. Thus, simplifying (10) and solving for S, the maximizing value S^* is found to be:

(11) $S^* = \mu\gamma \frac{\beta_1 - 1}{\beta_1} \theta^{\frac{1}{\beta_1} - 1} \frac{y}{\delta} - \frac{V}{\theta}$

Expression (11) identifies the willingness to pay of the imitator to avoid a litigation in court as a positive function of the compensation that he would be expected to have to pay $(\mu\gamma\frac{y}{\delta})$, and of the impact on the innovator (θ), and as a negative function of uncertainty and of the legal costs for the plaintiff. The strike price of the imitation option, therefore, will be partly determined by this term, which is a negative function of the costs that the innovator has to incur for recourse to legal action. In other words, the less efficient the judicial system (or the lower the protection accorded to the innovator), the lower the exercise price of the option to imitate. Since β_1 is a negative function of the variance of the cash flow coming from the innovation, on the other hand, i.e. $\frac{\partial \frac{\beta_1 - 1}{\beta_1}}{\partial\sigma} = \frac{1}{(\beta_1 - 1)^2}\frac{d\beta_1}{d\sigma} \le 0$ the lower uncertainty, the higher will be the willingness to pay of the imitator to settle with the innovator.

3. The decision to imitate

Given the solution to the ex post problem in (10), the ex ante problem for the perspective imitator is to decide whether to proceed to the endeavor to uncover the innovator's trade secrets and undergo the predicted costs from this action. The value matching condition that determines the point at which the imitator is just indifferent between starting the action and foregoing it is given by equation (3). Substituting the value of Dy^{β_1} found in (8), the corresponding equality for marginal increases in the stochastic variable (the "smooth pasting condition") is found to be:

$$(12) \quad \beta_1 B y^{\beta_1 - 1} = \frac{\gamma}{\delta}(1 - \mu\theta^{\frac{1}{\beta_1} - 1})$$

Using (3), (8) and (12), we can now determine the value of the critical entry point y_m for the imitator (the "imitation threshold"), and the value of the option to imitate, i.e. of the threat faced by the innovator:

$$(13) \quad \frac{y_m}{\delta} = [\gamma(1 - \mu\theta^{\frac{1}{\beta_1} - 1})]^{-1}\frac{\beta_1}{\beta_1 - 1}(K + \lambda C - \frac{V}{\theta})$$

$$(14) \quad By^{\beta_1} = y_m^{1-\beta_1}(1-\mu\theta^{\frac{1}{\beta_1}-1})\frac{y^{\beta_1}}{\delta\beta_1}$$

Expression (13) and (14) both indicate the way imitation may be encouraged by a high prospect for gains and high costs for the innovator to seek legal compensations, while it may be discouraged by high imitation costs and risks to be found liable in court. Notice that, since $\frac{\partial \frac{\beta_1}{\beta_1 - 1}}{\partial\sigma} = -\frac{1}{(\beta_1 - 1)^2}\frac{d\beta_1}{d\sigma} \geq 0$, the higher uncertainty (the lower the parameter β_1), the later the imitator may find convenient to act and the lower, correspondingly, the threat posed for the innovator.

4. The innovator's behavior under the threat of imitation

Once the innovator is in business, her behavior will be governed by the attempt to maximize expression (2). More precisely, she will seek to determine the optimal level of trade secrecy costs C^*, conditioned on what she knows on the threat posed by the possible imitators. Assuming perfect information on the imitator's reaction function, this implies determination of :

$$(15) \quad C^* = \arg\max[U_N = \frac{y}{\delta} - C - y_m^{1-\beta_1}\gamma(1-\mu\theta^{\frac{1}{\beta_1}-1})\frac{y^{\beta_1}}{\delta\beta_1}]$$

Taking the first derivative of the function in parenthesis and equating it to zero as before yields the unique maximizing value:

$$(16) \quad C^* = (1-\mu\theta^{\frac{1}{\beta_1}-1})\lambda^{\frac{1}{\beta_1}-1}\frac{\beta_1 - 1}{\beta_1}\gamma\frac{y}{\delta} - \frac{1}{\lambda}(K - \frac{V}{\theta})$$

Equation (16) expresses the innovator's willingness to pay to privately protect herself as a positive function of the damages that she may suffer from imitation ($\gamma\frac{y}{\delta}$), of the effectiveness of secrecy expenditures (λ) and of the costs to recourse to courts (*V*), and as a negative function of uncertainty, the compensation that could be expected in a formal litigation (μ) and the effectiveness of the expected efforts of the imitator to settle out of court (θ).

From equation (16), in particular, we can reach the conclusion that the innovator will be willing to invest in secrecy or in other forms of self protection, the **lower** the expected amount of legal protection and the lower uncertainty. In other words, a more effective judicial system and a stronger formal claim (as in the case of patent rights) discourage secrecy and encourage litigation and the more so, the more volatile the source of gains object of the possible dispute. Note also that an increase in own protection costs *C* increases both the exercise price of the innovator and the imitator, that is, it makes both activities more costly and , in general, innovation less likely to occur and, once occurred, less likely to spread.

5. The decision to innovate

Consider now the impact of all (predictable) actions on the decision to innovate. This decision will be governed by the value matching condition in (5), which, after substitution of (14) and (15), can be written as follows:

$$(17) \quad Ay^{\beta_1} = [1-\gamma(1-\mu\theta^{\frac{1}{\beta_1}-1})\lambda^{\frac{1}{\beta_1}-1}]\frac{y}{\delta}+\frac{1}{\lambda}(K-\frac{V}{\theta})-I$$

The correspondent smooth pasting condition is obtained differentiating both sides of (17) w.r.t. y :

$$(18) \quad \beta_1 Ay^{\beta_1-1} = [1-\gamma(1-\mu\theta^{\frac{1}{\beta_1}-1})\lambda^{\frac{1}{\beta_1}-1}]\frac{1}{\delta}$$

Again from (17) and (18) we can solve to obtain the value of the entry point y_N for the innovator (the “innovation threshold”) and the value of the option to innovate:

$$(19) \quad \frac{y_N}{\delta} = [1-\gamma(1-\mu\theta^{\frac{1}{\beta_1}-1})\lambda^{\frac{1}{\beta_1}-1}]^{-1}\frac{\beta_1}{\beta_1-1}[\frac{1}{\lambda}(\frac{V}{\theta}-K)+I]$$

$$(20) \quad Ay^{\beta_1} = y_N^{1-\beta_1}\frac{y^{\beta_1}}{\delta\beta_1}$$

The threshold of innovation will be lower and innovation correspondingly encouraged, the lower uncertainty, the lower investment costs, the higher imitation costs, the lower the innovator's loss from imitation, and the more effective the trade secrecy cost parameters. The size of the possible compensation from court action and lower legal costs will also encourage, coeteris paribus, innovation and correspondingly reduce the value of the option to delay the investment in (20).

6. The social problem

The problem for society is now to determine a distribution of rights, through the costs of the court system, in a way that optimally balances the need to encourage innovation and, at the same time, to spread it as much as possible.

We follow the method used by Dixit and Pindyck (1994, pp. 272-277) to compute the rate of entry in an industry with stochastic uncertainty. Start with the innovation problem and consider the case of N would-be innovators distributed over the range $(-\propto, y_N)$. Let $g(y)$ be the density function of an initial draw of the perspective net gain y and $G(y)$ the corresponding distribution function. Of the possible innovators, for a number $N(1-G(y_e))$ there is an increase in expected gains that justifies immediate adoption of the investment. The rest remain waiting for a possible increase in net gains that may induce them to invest.

The agents who are candidates for the innovation are distributed between the maximum value y^M of the expected gain and the innovation threshold value y_N. Let $N\varphi(y)$ denote the density of these agents at location y and let $dh = \frac{\sigma}{\sqrt{dt}}$ be a small variation of net gain. For the density to be stable over time, we must have:

(21) $N\varphi(y)dh = Ng(y)dh + pN\varphi(y-dh)dh + (1-p)N\varphi(y+dh)$

where $p = \frac{1}{2}(1+\frac{\sqrt{dt}}{\sigma})$. Expression (21) states the condition of stationarity of the distribution at any payoff level as requiring that the agents leaving (to the right) the location because of payoff increases be exactly counterbalanced by agents arriving in the location because of payoff decreases. Eliminating the common terms and using a Taylor expansion, expression (21) becomes a differential equation:

(22) $\frac{1}{2}\sigma^2\varphi''(y) - \varphi'(y) + g(y) = 0$,

whose general solution has the form:

(23) $\varphi(y) = C_1 \exp(b_1 y) + C_2(-b_2 y) + \varphi_0(y)$

where b_1 and b_2 are the roots of the quadratic expression:

(24) $\frac{1}{2}\sigma^2 b^2 - b = 0$

while $\varphi_0(y)$ is a specific solution of the differential equation in (22). Since the expression in the second root decreases with y, it cannot be associated with an equation describing the adoption of the R&D investment under a payoff increase . The second term on the right hand side of (23) must thus be zero.

Assume now that $g(y) = \exp(y - y_M)$, i.e. that the initial draw of y is a density of the exponential type. It can be easily verified that a specific solution $\varphi_0(y)$ is given by:

(25) $\varphi_0(y) = \exp(y - y_M)/(1 - \frac{1}{2}\sigma^2)$,

which is nonnegative if $\sigma^2 \leq 2$. Consider now the segment immediately to the left of y_N. The stability of the distribution over time requires that:

(26) $N\varphi(y)dh = Ng(y)dh + N\varphi(y - dh)$

since the right hand part is missing due to the fact the the agents have left to adopt the R&D project . Letting dh go to zero, we obtain: $\varphi(y_N) = 0$.

Using this result, we can find a value for the constant C_2 and a general solution for expression (24):

(25) $\varphi(y) = -\frac{\exp[y_N(1+\gamma) - \gamma y - y_M]}{(1 - \frac{1}{2}\sigma^2)} + \frac{\exp[y - y_M]}{(1 - \frac{1}{2}\sigma^2)}$

The rate R at which innovators will enter the market EGS is the fraction p of the $N\varphi(y + dh)dh$ workers located just at the left of y_N. Using a Taylor expansion:

(26) $\frac{1}{2}N[\varphi'(y_N)dh - \varphi(y_N)]dh = \frac{1}{2}N\varphi'(y_N)(dh)^2 = \frac{1}{2}\varphi'(y_N)\sigma^2 dt$

i.e.:

(27)

$$R = \frac{1}{2}N\sigma^2\varphi'(y_N) = \frac{1}{2}N\sigma^2 \frac{\exp[y_M - y_N]}{(1-\frac{1}{2}\sigma^2)}(1+b)$$

Using a similar method, for M imitators, we can conclude that their rate of entry R_m is :

(28) $$R_m = \frac{1}{2}M\sigma^2\psi'(y_N) = \frac{1}{2}M\sigma^2 \frac{\exp[y_M - y_m]}{(1-\frac{1}{2}\sigma^2)}(1+c)$$

These two results can be stated, more generally, as indicating that the rate of innovation and imitation will be an exponential function of the respective difference between the maximum value of the payoff and the entry point. More generally, and intuitively, we can conclude that the larger these differences, the larger will be, coeteris paribus, the rates of innovation and imitation in a society.

How do we solve, then, the social problem? Given the need to balance the incentives to innovate and to imitate, the result in equation (28) implies that society, in fixing the cost of judicial services, has to minimize the two differences in (27) and (28). This in turn implies that if the same weight is given to both incentives, the threshold of innovation should be equalized to the threshold of imitation: i.e. $y_N = y_m$. Using (13), (15) and (19), we find:

(29) $$\frac{V^*}{\theta} = \frac{\lambda}{(1-a)-\lambda}[(\frac{1-\lambda(1-a)}{\lambda})K - aI - \frac{\beta_1 - 1}{\beta_1}\frac{y}{\delta}]$$

where $a = \frac{\rho}{2\rho - 1}$ and $\rho = \gamma(1-\mu\theta^{\frac{1}{\beta_1}-1})$.

In (29), a is a measure of the rate of return to imitation, since it depends on the amount of the innovator’s income that the imitator is able to capture, net of the recovery rate from the innovator, and of a negative function of the effectiveness of the imitator's countervailing costs.

Thus, in order to equalize the two thresholds, judicial costs should be set at a level depending on the effectiveness parameter λ of the trade secrecy costs. For low values of this parameter, judicial costs should be higher the higher imitation costs, and the lower innovation costs and gain prospects from innovation. Vice-versa, for high values of λ, judicial costs should fall with high imitation costs and rise with innovation costs and gain prospects from innovation. In other words, if trade secrecy practices are poorly effective, society should be committed to compensate the ineffectiveness of individual behavior through a higher efficiency of the judicial system, while the opposite should occur if trade secrecy is effective.

More specifically, consider the limiting, but illustrative case where the innovator's protection costs are completely effective, i.e. $\lambda = 1$. In this case, expression (29) becomes:

$$(30) \quad \frac{V^*}{\theta} = K - I - \frac{\beta_1 - 1}{a\beta_1}\frac{y}{\delta}$$

Thus, under the simplifying hypothesis of perfect effectiveness of private protection costs, the optimal level of legal costs imposed on the innovator to protect her claim with the law will be perfectly determined. It will equal imitation investment costs minus the sum of innovation investment costs plus the value of expected gains corrected for uncertainty and the return to imitation. If imitation costs are lower than innovation costs, as one would expect in most cases, there will be no need for legal protection, since private protection will be more than sufficient to deter imitation.

Conclusions

Innovation and imitation can be seen as complementary investments tied by reciprocal options to defend, appropriate and recover part of the gains generated by a discovery or an invention. While innovators hold the original option to invest in research and development to foster innovation, innovators and the imitators, in particular, hold options to act against each other (liability options) to secure the largest possible share of the invention/ discovery pay-off. Under dynamic uncertainty, the incentives to both parties to act will be reduced by uncertainty, and the possible intervention of the law will also be deflated by an increase in the volatilities of the cash flows envisaged from the action. In principle, the intervention of the law should not be necessary, since the innovator has the means to discourage the imitator through trade secrecy and other direct costs. The possible ineffectiveness of the innovator's protection efforts, however, may make some public protection scheme indispensable, to ensure that a sufficient incentive is provided to both parties, respectively, to innovate and diffuse. This type of protection should take the form of a liability rather than of a property rule and its costs should be a function of variables such as the uncertainty level and the effectiveness of actions and counteractions on the part of the two disputants. Indeed, the results obtained suggest that public intervention should only be used to restore the possible ineffectiveness of private protection measures.

BIBLIOGRAPHY

Denicolò, V., (1996), "Patent Races and Optimal Patent Breadth and Length", Journal of Industrial Economics, n.44 (September), pp. 249-65.

Dixit, A. and Pindyck, R. (1994), *Investment under Uncertainty*, Princeton University Press,

Gallini, N.T. (1992), "Patent Policy and Costly Imitation", Rand Journal of Economics, 23 (Spring), pp. 52-63.

Gilbert, R. and Shapiro, C. (1988), "Optimal Patent Length and Breadth", Princeton University Woodrow Wilson School of Public and International Affairs. John M. Olin Program for the Study of Eco. Org. Amd Pub. Pol. Discussion Papers, n.28 (october), pp.1-9.

Klemplerer, P. (1990), "How Broad Should the Scope of Patent Protection Be?", Centre for Economic Policy Research Discussion Paper Series (U.K.), n.392 (March), pp. 1-21.

Scandizzo, P.L. and Knudsen, O. (1999), "The Cost-Benefit Analysis of Biotechnology Projects", Paper presented at the International Conference on "The Shape of the Coming Agricultural Biotechnology Transformation: Strategic Investment and Policy Approaches from an Economic Perspective", June, Rome-Ravello.

Scandizzo, P.L. (1999), "Ownership, Appropriation and Risk", in McCArthy, N., Swallow, B., Kirk, M. and Hazell, P. (eds), *Property Rights, Risk & Livestock Development in Africa*, IFPRI, Washington DC, pp. 211-239.