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Choosing the Scope of Trade Secret Law when Secrets Complement Patents

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Abstract. We present a model where an incumbent firm has a proprietary product whose technology consists of at least two components, one of which is patented while the other is kept secret. At the patent expiration date, an entrant firm will enter the market on the same technological footing as the incumbent if it is successful in duplicating, at certain costs, the secret component of the incumbent's technology. Otherwise, it will enter the market with a production cost disadvantage. We show that under some conditions a broad scope of trade secret law is socially beneficial despite the innovator is over-rewarded.

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1. Introduction

The main instruments of intellectual property policy to promote innovations are the legal protection of patents and the legal protection of commercial and industrial secrets. As Friedman, Landes and Posner (1991) point out, trade secret law supplements the patent system as "Inventors choose trade secret protection when they believe that patent protection is too costly relative to the value of their invention, or that it will give them a reward substantially less than the benefit of their invention…, either because the invention is not patentable or because the length (or other conditions) of patent protection is insufficient". According to the authors, trade secret law is confined to protecting against conduct that is independently wrongful, that is, that violates some independent common law principle. Both reverse engineering and independent reinvention are admissible, as they often generate knowledge that will make it possible to improve on the original product. Besides, as trade secret protection has virtually no expiration date, the prohibition of reverse engineering and independent invention would make it stronger and preferable to patents. Nevertheless, citing a case like *E.I du Pont de Nemours & Co. v. Christopher* and considering that in assessing damages courts take account of trade secret's commercial value, the authors recognize the statement that there is no law of trade secrets as too bold.

Since patents and trade secrets have generally been perceived as mutually exclusive, with few exception the law and economics literature has separately concentrated on the design of optimal patent policy and on the design of optimal trade secret policy.[1] However, while the interest in optimal patent design is long standing and has given rise to large

[1] In some papers the choice between patent and trade secret protection is explicitly considered, but the strength of trade secret protection is treated as exogenous (e.g., Gallini, 1992; Denicolò and Franzoni, 2008; Cugno and Ottoz, 2006). For a discussion regarding the interplay between optimal patent and trade secret protection, see Erkal (2004).

literature in the field, whose origins can be dated back to Nordhaus (1969),[2] the issue of the optimal strength of trade secret protection has received little attention until a short time ago. Only recently, starting from a provocative paper by Bone (1998), some authors have widely discussed the question of whether trade secret deserves a legal protection which goes beyond the contract law or the tort law. In the words of Lemley (2008), "Trade secret law is a puzzle. Courts and scholars have struggled for over a century to figure out why we protect trade secrets. …It seems odd, though, for the law to encourage secrets …..I argue that, paradoxically, trade secret law actually encourages disclosure, not secrecy. Without legal protection, companies in certain industries would invest too much in keeping secrets." Trade secret laws are then justified by the economic benefits that flow from their existence, in particular incentives for innovators to spend less money protecting secret information and for imitators attempting to appropriate secret information. According to Risch (2007) and Lemley (2008), the reduction of such costs is a sufficient reason for the existence of a trade secret law as a separate doctrine, whereas Bone (1998) has an opposite opinion.

The papers cited above prevalently refer to cases in which a proprietary innovation is protected by trade secret only. However, in spite of a common misperception of an alternative between patents and trade secrets, an innovator can use both intellectual property rights to protect different aspects of the same invention, as courts have long held that a published patent does not invalidate those trade secrets that are not disclosed in the patent itself.[3] Trade secrets can, in fact, be used in lieu of patents but, more importantly,

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[2] A selection of the first contributions includes Tandon (1982), Gilbert and Shapiro (1990), Klemperer (1990), Gallini (1992).

[3] Interesting examples of patent-secret mix reported by Arora (1997) include German organic dyestuff in the nineteenth century, the Haber Bosch process for producing ammonia, the industrial diamond process technology by General Electric in the fifties. Court decisions such as *C&F Packing v. IBP and Pizza Hut* (Fed. Cir. 2000) illustrated by Jorda (2004) and *Celeritas*

they can be relied upon at the same time and side by side with patents to protect any given invention. With patents and trade secrets it is clearly possible to cover additional subject matter, strengthen exclusivity and extend intellectual property rights.

As patent protection is meant to assure the innovator with a reward just sufficient to cover her costs, it is clear that the association of patents and trade secrets can result in an over-reward of the innovator well beyond the one necessary to preserve the innovation incentive. Thus, a relevant policy issues arises. If the policy makers worry about the negative effects of a patent length reduction on the research incentive for innovations whose components are all protectable only by patents, do social benefits result from a decrease in trade secret protection, given the patent length, when the owner of the patent-secret mix is over-rewarded?

In this paper we attempt to face this issue by using a model in which the social cost associated with the mixtures of patents and trade secrets includes, besides dead-weight losses, the costs borne by an entrant trying to duplicate that part of the technology protected by trade secret. Leaving aside, for sake of simplicity, costs borne by the two firms to illicitly obtain or protect information, we can concentrate on the relations between duplication costs (by legal means) and social welfare, along the lines of previous models present in the literature (Gallini, 1992; Maurer and Scotchmer, 2002; Denicolò and Franzoni, 2008).[4] A special feature of our model is nevertheless the relation between the probability of duplication and the scope of trade secret law.

Technologies v. Rockwell International (Fed. Cir. 1998) provide more recent examples of a complementary use of patents and trade secrets. Moreover, it is well known that in the software industry source code secrecy frequently complements patents.

[4] Accurate analyses of the relation between costs incurred by rival firms in order to protect or misappropriate secret information and the scope of trade secret law can be found in the cited papers by Bone, (1998), Risch, (2007), and Lemley (2008).

Considering a situation in which transaction costs of trade secret licensing are prohibitive, we determine conditions under which a strong legal protection of trade secret is socially beneficial even if it implies innovator's over-rewarding. The paper is organized as follows. In Section 2 the model is presented and some legal issues are briefly discussed. Section 3 is dedicated to the design of optimal secret protection when secrets complement patents and Section 4 concludes.

2. Employee Mobility, Knowledge Spillover, and Duplication Costs

The model we will put forward in Subsection 2.2 below refers to a duopoly environment where employee mobility is subject to some contractual and legal restrictions intended to limit spillovers of proprietary non patented information. The scope of trade secret protection is identified with the strength of these restrictions, which we shortly expound in the following subsection.

2.1. Labor Mobility Restrictions

Apart form clearly illegal means for appropriating secret information, such as industrial espionage, employee mobility seems to be the main cause of technology spillovers between firms.[5] To the purpose of limiting harmful losses of proprietary information, in employment contracts firms may insert post-employment clauses, known as "post-employment covenants not to compete". In the absence of these covenants, in some cases firms may still resort to a lawsuit by appealing to the "inevitable disclosure doctrine" or similar arguments. The scope of trade secret law largely depends on the degree of jurisdictions' acceptance (and enforcement) of these protection tools.

While post-employment covenants consist of promises by employees not to work for a competitor for a specified period after employment ends, the inevitable disclosure doctrine

[5] With reference to high technology districts see, for example, Saxenian (1994) and Gilson (1999).

refers to cases in which such covenants are not signed in the hiring contracts or during the employment relationships. This legal doctrine assumes that if an employee has knowledge of trade secrets, and accepts a similar job with a direct competitor in a highly competitive firm, he or she will "inevitably" disclose the trade secrets in the course of performing his or her new employment duties, so that when the former employer would suffer "irreparable harm" from disclosure this sort of employee mobility should be restricted irrespective of the existence of post-employment covenants. Classical cases where the inevitable disclosure doctrine has been adopted are *PepsiCo., Inc. v. Redmond* (7th Cir. 1995) 54 F.3d 1262 and *IBM v. Papermaster*, 2008 WL 4974508 (S.D.N.Y.), where the notion of "irreparable harm" is introduced. An example of rejection is *Schlage Lock Company v. Whyte* (2002) 101 Cal. App. 4th 1443.

It is worth noting that while enforceability of post-employment covenants not to compete are provided for by the law in almost all U.S. and E.U. jurisdictions, with more or less differences and with the notable exception of California where they are banned, the adoption of inevitable disclosure doctrine is typical of several, but not all, U.S. courts. Besides California, where the doctrine is explicitly refused, some jurisdictions such as Michigan, Missouri, Maryland and Minnesota expressed a few reservations about its application. Despite European courts never refer to some form of inevitable disclosure doctrine, something similar has nevertheless been formulated by the Court of Appeals of Paris in a case reported by Thiébart (2003), where the employee did not signed any post-employment restrictive clause. In its decision rendered on November 10, 1994, the court ruled that "if it is legitimate, in all cases, that an employee harvest the fruit of the experience he gained with prior employers, which constitutes for the employee a normal factor of enhanced value, this does not justify unfair behavior which can consist in disorganizing a former employer by massive employee departure or in disclosing manufacturing secrets and technical or commercial knowledge in order to enable the latter to capture the clients of the former employer". In any case, it is obvious that where the inevitable disclosure doctrine, or some equivalent argument, is adopted, the scope of trade secret law tends to be broader than elsewhere.

The differences in conditions for enforceability of post-employment covenants mainly concern geographical and temporal restrictions, employees' job positions with respect to access to trade secrets, and employee financial compensations. For example, financial compensation to the employee must be explicitly provided for in employment contracts (personal or collective) in almost all E.U. states, while other jurisdictions –notably, the overwhelming majority of states in the U.S., Norway, Switzerland, Iceland and, inside E.U., Great Britain– do not require special consideration in labor contracts for worker's agreement to a non competition covenant. As far as California is concerned, Business and Professions Code section 16600 provides that "every contract by which anyone is restrained from engaging in a lawful profession, trade, or business of any kind is to that extent void." Californian courts have interpreted section 16600 "as broadly as its language reads",[6] so that they not only reject the doctrine of inevitable disclosure, but they also refuse to enforce post-employment covenants. See Gilson (1999), where the high labor turnover in Silicon Valley is ascribed to the weakness of trade secret protection in California, in contrast with the low employee mobility in Route 128 district governed by Massachusetts trade secret law.

2.2. The Model

Let's consider two firms, labeled I (incumbent) and E (entrant). Firm I owns a proprietary product jointly protected by patents, whose duration is t, and trade secrets,

[6] *Scott v. Snelling & Snelling, Inc*. 732 F. Supp. 1034, 1042 (N.D. Cal 1990).

which have no fixed expiration date.[7] For example, we can assume that at the time the patent was filed firm I disclosed the best mode for carrying out the invention; successively, firm I discovers a better best mode which it can keep secret without bearing the risk of patent invalidation. A possible alternative hypothesis is that the proprietary product consists of several parts, some of which are patented while others are kept secret. In any case, at the time t firm E attempts to duplicate the secret information by spending resources at this aim. It may enter the market bearing the same production costs of firm I, if duplication is successful, or higher costs –those associated with the information disclosed in the patent– if the duplication attempt fails.[8]

We assume that each employee of the incumbent firm has only a piece, more or less important, of information on the whole set of secrets owned by his or her employer. To the purpose of duplicating the secret parts of firm I's technology, firm E may take advantage of some knowledge spillover, whose intensity essentially depends on the employee mobility between the two firms. Employee mobility in turn depends on the scope of trade secret law, more specifically on the enforceability of post-employment covenants not to compete, and on the adoption or rejection by courts of the inevitable disclosure doctrine (in the U.S.) or similar legal arguments.

By utilizing the set of information obtained through employee mobility, whatever its dimension, at time t firm E will spend resources to duplicate all components of firm I's

[7] Although an innovator can often choose the extent patents and trade secrets combine with one another, in this paper we assume a given patent-secret mix. For a model where the patent-secret mix results from a maximizing choice, see Ottoz and Cugno (2008).

[8] Patents are assumed to be broad enough to make any non-infringing imitation impossible. This hypothesis is harmless to our purposes, as the introduction of patent breadth as a control instrument responsible of the possibility of patent imitation and related costs, would not modify conclusions. In particular, in our model a patent guaranteeing temporary monopoly would still be optimal, as in Gallini (1992).

technology protected by trade secret. Given the sum spent for duplication, called K, the probability of success, γ, will increase with the dimension of the preexisting set of disposable information, which in turn diminishes as the scope of trade secret law increases. In what follows, for sake of simplicity we treat the scope of trade secret law as a continuous variable depending on the conditions required by the relevant courts for enforcing post-employment covenants or applying the inevitable disclosure doctrine.

On these bases, and adopting the usual convexity hypothesis for a cost function, we assume that the probability of duplication success, the duplication effort, and the scope of trade secret law, are linked by the relation

$$K = \theta g(\gamma), \tag{1}$$

where $g(0) = 0$, $g'(\gamma) > 0$, $g''(\gamma) > 0$ and the shift parameter θ is a measure of the duplication difficulty which increases as the scope of trade secret law is broadened. Note that this approach is very similar to the one adopted by Takalo (2004) in a model with costly patent imitation: the only difference is that in our case the duplication difficulty depends on the strength of trade secret protection, not on patent breadth.

If the attempt is successful, from time t firm E will compete on the same technological footing with firm I, so that it will obtain for ever a stream of symmetric-cost duopoly profits equal to π_{SD}^{E}. If the attempt fails, firm E may enter the market with a production cost associated with the information disclosed in the patent application, that is with higher costs than firm I. In this case firm E will gain a stream of asymmetric-cost profits $0 \leq \pi_{AD}^{E} < \pi_{SD}^{E}$. Given that r represents the discount rate, firm E will then choose γ by maximizing

$$\Pi^{E} = \frac{\gamma \pi_{SD}^{E} + (1-\gamma)\pi_{AD}^{E}}{r} - \theta g(\gamma). \tag{2}$$

If an interior solution $0 < \gamma < 1$ exists, the privately optimal value of γ will be given by

$$g'(\gamma) = \frac{\pi_{SD}^{E} - \pi_{AD}^{E}}{r\theta}, \tag{3}$$

from which

$$\frac{d\gamma}{d\theta} = -\frac{\pi_{SD}^{E} - \pi_{AD}^{E}}{g''(\gamma) r\theta^2} = -\frac{g'(\gamma)}{g''(\gamma)\theta}. \tag{4}$$

So, as it was logical to expect, an increase in the scope of trade secret law reduces the privately optimal level of γ.

3. Choosing the Scope of Trade Secret Law

In this section we first use our simple duopoly model to determine the optimal scope of trade secret law for a given patent length. In doing this we assume that, due to high transaction costs, trade secret licensing is not mutually convenient. Then we consider some special cases characterized by different market behaviors.

3.1. Optimal Scope

Let's indicate with Δ_M the stream of dead-weight loss associated with monopoly, with Δ_{SD} the stream associated with symmetric-cost duopoly, and with Δ_{AD} the stream associated with asymmetric-cost duopoly. With probability $1-\gamma$ firm E is not successful in the duplication attempt so that after patent expiration firm I will enjoy a production cost advantage. In this case the stream of dead-weight loss will be Δ_M during patent life and $\Delta_{AD} \leq \Delta_M$ soon after the expiration date. If, on the opposite, firm E is successful in the duplication attempt, after patent expiration the stream of deadweight loss will be $\Delta_{SD} < \Delta_{AD}$. This event has probability γ. Social expected cost of the patent-secret mix, SC, is the sum of the expected present value of dead-weight losses and of the expected present value of the cost borne by firm E to duplicate the secret, minus the present value of the perpetual flow of dead-weight losses associated to the symmetric-cost duopoly (which is not dependent on the patent-secret mix). Then, defining $T = 1 - e^{-rt}$,

$$SC = T\frac{\Delta_M}{r} + (1-T)\left(\frac{\gamma\Delta_{SD} + (1-\gamma)\Delta_{AD}}{r} + \theta g(\gamma)\right) - \frac{\Delta_{SD}}{r}, \tag{5}$$

where $\Delta_{SD} < \Delta_{AD} \leq \Delta_M$.

Minimizing SC with respect to θ and T while preserving the desired innovation incentive, we in general can determine the socially optimal combination of patent length and trade secret scope for innovations of the kind we are dealing with. As the choice of patent length is, nevertheless, relevant also for innovations whose components are all protectable only by patents, may be that policy makers wish to fix it at a level higher than that which would solve the above problem. Let's then consider the case where at the outset T and θ are such that the innovator is over-rewarded. The problem is to verify if a reduction in the scope of trade secret law, diminishing the over-reward of the innovator for the given T, also reduces the social cost of the patent-secret mix. Proposition 1 below shows that under certain conditions the opposite happens.

Before proceeding, it is useful to define the elasticity of probability of firm E's duplication success with respect to the expense for duplication. As we will see, this elasticity, given by $\eta = (d\gamma / dK)(K / \gamma) = g(\gamma) / g'(\gamma)\gamma$, will turn to be crucial for our result.

Proposition 1. Suppose the inequality

$$\eta + \frac{d\eta}{d\gamma}\gamma > \frac{\Delta_{AD} - \Delta_{SD}}{\pi_{SD}^E - \pi_{AD}^E} \tag{6}$$

holds for all $\gamma \in [\gamma_{\min}, \gamma_{\max}]$, where $\gamma_{\min}$ and $\gamma_{\max}$ are the probabilities of duplication success corresponding to the maximum and minimum scope of trade secrete law, respectively. Then, the maximum scope of trade secret law turns out to be socially optimal despite the patent-secret holder is over rewarded.

Proof. By using equations (3), (4) and (5) we can verify that if

$$\frac{(g'(\gamma))^2 - g(\gamma)g''(\gamma)}{(g'(\gamma))^2} > \frac{\Delta_{AD} - \Delta_{SD}}{\pi_{SD}^E - \pi_{AD}^E} \tag{7}$$

the derivative $dSC / d\theta$ is negative. (See the Appendix for details.) On the other hand, differentiating $\eta = g(\gamma) / g'(\gamma)\gamma$ and rearranging terms, we have

$$\frac{(g'(\gamma))^2 - g(\gamma)g''(\gamma)}{(g'(\gamma))^2} = \eta + \frac{d\eta}{d\gamma}\gamma . \tag{8}$$

Thus, inequality (7) corresponds to inequality (6). The enunciate immediately follows. ■

The rationale of Propositions 1 is that when condition (6) holds an increase in the scope of trade secret law increases expected innovator's profits more than it decreases the expected value of consumer surplus net of duplication costs, so that social welfare increases. In other words the beneficial effect of a high legal protection of trade secret is due to the fact that this sort of protection allows society to save on duplication costs that would be otherwise borne by firm E. This saving may be sufficient to more than compensate the increase of the expected present value of dead-weight losses caused by the reduction of the probability that the duplication attempt is successful.

It is worthwhile noticing that the hypotheses we have formulated on the relation between γ, K and θ are crucial for the above result. Other models assume that the probability of success in duplicating the secret technology is equal to 1 provided that the entrant invests a given amount of resources for that purpose and that there exists a positive probability (obviously smaller than 1) of total leakage of the secret. (See Denicolò and Franzoni, 2008; see also Gallini, 1992, where the duplication cost of the secret doesn't play any role, but there is a probability of total leakage and a probability equal to 1 of non infringing patent imitation if the imitator invests for that goal a sufficient sum.) In these circumstances, if the probability of total leakage is negatively affected by the scope of trade secret law, it would be always optimal to adopt a policy of minimum trade secret protection. In fact, as duplication expenses do not depend on policy makers' choices, it would be advisable to get the maximum probability of total leakage.

Remark 1. If the quantity $\eta + (d\eta / d\gamma)\gamma$ monotonically decreases with γ increasing, the maximum scope of trade secret law can be socially optimal even if inequality (6) is reversed in some subinterval of $[\gamma_{\min}, \gamma_{\max}]$. The reason is that when the graph of $\eta + (d\eta / d\gamma)\gamma$ with γ increasing cuts the horizontal line $(\Delta_{AD} - \Delta_{SD})/(\pi_{SD}^{E} - \pi_{AD}^{E})$ from above, at the intersection point SC is at a maximum. Then, if there are no other intersection points, SC will be minimized either at $\gamma_{\min}$ or at $\gamma_{\max}$.

3.2. Some Special Cases

To gain more insights into the meaning and relevance of condition (6) it is useful to consider different market behaviors under linear output demand and constant marginal costs. Assume therefore the inverse demand function $P = a - Q$, where P is market price and Q is total output. Also assume that, with respect to the superior technology which allows to produce at constant marginal costs equal to zero, the inferior technology implies a constant cost disadvantage equal to ε.[9] Under the above linearity assumptions and the additional hypothesis that the function $g(\gamma)$ is iso-elastic ($d\eta / d\gamma = 0$), condition (6) can be written

[9] No loss of generality is implied by setting marginal costs associated with the superior technology equal to zero. If these costs were supposed positive, the demand function could simply be rescaled to produce the same results.

$$\eta > \frac{\Delta_{AD} - \Delta_{SD}}{\pi_{SD}^{E} - \pi_{AD}^{E}} = \frac{(1/2)(P_{AD})^2 + \varepsilon q_{AD}^{E} - (1/2)(P_{SD})^2}{P_{SD} q_{SD}^{E} - (P_{AD} - \varepsilon) q_{AD}^{E}}, \tag{9}$$

where q_i^E, $i = SD, AD$, stands for firm E's output.[10] In what follows we will examine Cournot competition (integrated with limit pricing), Stackelberg competition with the incumbent firm acting as the quantity leader, Bertrand competition, collusion, and incumbent's post-patent monopoly. In this way we can obtain approximate numeric information about the pairs (η, ε) for which, given the market behavior, condition (6) in Proposition 1 is fulfilled.

• *Cournot competition*. Suppose $\varepsilon < P_M = a/2$, where P_M stands for monopoly price. Under Cournot duopoly, where each firm chooses a quantity to produce that maximizes its profit flow given the expectation that the rival firm maintains its output level fixed, firm E's outputs and market prices are given by

$$q_{SD}^{E} = \frac{a}{3}, \quad q_{AD}^{E} = \frac{a - 2\varepsilon}{3}, \quad P_{SD} = \frac{a}{3}, \quad P_{AD} = \frac{a + \varepsilon}{3}.$$

Then, condition (9) becomes

$$\eta > \frac{8a - 11\varepsilon}{8a - 8\varepsilon}.$$

Since the ratio $(8a - 11\varepsilon)/(8a - 8\varepsilon)$ decreases as ε increases, approaching the value of $5/8$ as ε tends to the point $a/2$, at which and above the incumbent firm enjoys full monopoly power even after patent expiration, a necessary condition for inequality (9) to be satisfied is $\eta > 5/8$. For $\eta > 5/8$ inequality (9) can be fulfilled provided that ε is

[10] Since Pareto-optimal output is equal to a, deadweight-loss triangles are given by $(1/2)P_i(a - Q_i) = (1/2)(P_i)^2$, $i = SD, AD$. When $i = AD$, we must add the total extra cost born by firm E, that is εq_{AD}^{E}.

sufficiently high (see the shaded zone in Figure 1, panel *i*).[11] In particular, this event is the more likely the more relevant is the secret part of technology in terms of production costs and the more productive is at the margin the expense for duplication, that is for high levels of ε and η. This is due to the fact that for any θ duplication becomes more attractive as ε and η increase, so that a strong trade secret protection permits the society to save resources whose amount exceeds the expected present value of dead-weight losses associated with no duplication.

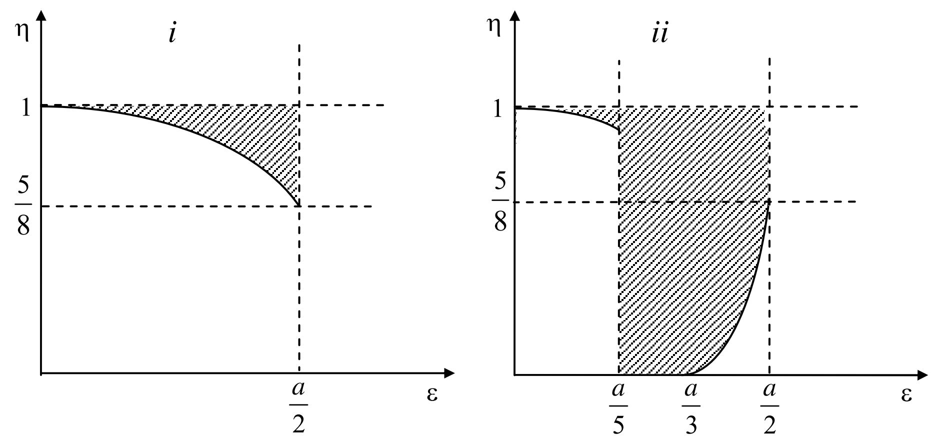

Figure 1. Condition (9) under Cournot competition (panel *i*) and limit pricing (panel *ii*).

• *Cournot competition and limit pricing*. In considering the above kind of competition we have ignored that when firm E fails in its duplication attempt the incumbent can prefer to deter entry by resorting to a limit pricing strategy, that is by setting the price at $P_{AD} = \varepsilon$. Specifically, comparing the value of the incumbent's profit flow under limit pricing with the corresponding value under asymmetric-cost Cournot duopoly, we can verify that limit

[11] Note that the elasticity η is upper bounded at 1 because the assumptions $g''(\gamma) > 0$ and η = constant are incompatible with $\eta \geq 1$.

pricing turns out to be a superior alternative for the incumbent if $a/5<\varepsilon<a/2$.[12] Suppose then that the two firms compete à la Cournot when the entrant succeeds in duplicating the secret technology or, if it does not succeed, when $\varepsilon<a/5$. Otherwise, the incumbent adopts a limit pricing strategy, so that if the entrant firm fails the duplication attempt and $a/5<\varepsilon$, its output will be zero. Then, since for $a/5<\varepsilon<a/2$ we have

$$q_{SD}^{E}=\frac{a}{3},\quad q_{AD}^{E}=0,\quad P_{SD}=\frac{a}{3},\quad P_{AD}=\varepsilon,$$

while for $\varepsilon<a/5$ the results for Cournot competition hold, condition (9) becomes

$$\eta>\begin{cases}\dfrac{8a-11\varepsilon}{8a-8\varepsilon}, & \text{for } \varepsilon<\dfrac{\text{a}}{5},\\[2ex] \dfrac{9\varepsilon^{2}-a^{2}}{2a^{2}}, & \text{for } \dfrac{a}{5}<\varepsilon<\dfrac{a}{2}.\end{cases}$$

Contrary to what happens in the case illustrated in panel *i* of Figure 1, the right-hand part of the inequality $\eta>(9\varepsilon^{2}-a^{2})2a^{2}$, starting from negative levels for $\varepsilon=a/3$, increases with ε until reaching the value of $5/8$ at the point $\varepsilon=a/2$, at which entry is no more a problem for the incumbent. This is explained by the fact that under limit pricing, while Δ_{AD} increases with ε as under Cournot competition, π_{AD}^{E} is null for all ε. It follows that $a/5<\varepsilon<a/3$, or $a/5<\varepsilon<a/2$ together with $\eta>5/8$, are sufficient conditions for inequality (9) to be fulfilled (see the shaded zone in Figure 1, panel *ii*). In these intervals, expected deadweight losses associated with no duplication are so small, or duplication is so attractive, that a strong trade secret protection which allows to save duplication expenses turns out to be beneficial for society.

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[12] The incumbent's profit flow under asymmetric-cost Cournot duopoly is given by $(a+\varepsilon)^{2}/9$. Comparing this value with the profit flow under limit pricing, $\varepsilon(a-\varepsilon)$, it follows that limit pricing turns out to be a strictly superior alternative for the incumbent if and only if $10\varepsilon^{2}-7a\varepsilon+a^{2}<0$, which implies $a/5<\varepsilon<a/2$.

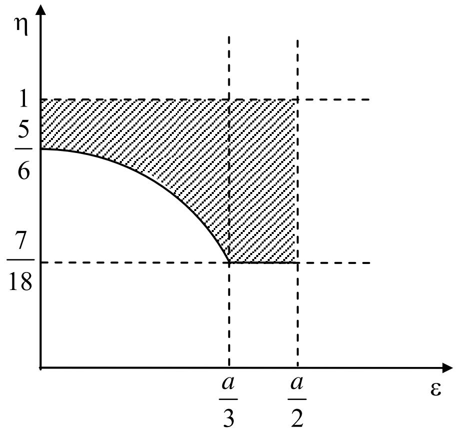

Figura 2. Condition (9) under Stackelberg competition

• *Stackelberg competition*. Suppose again $\varepsilon < P_M = a/2$. Under Stackelberg competition, with firm I being the quantity leader, firm E maximizes its profit flow treating firm I's output as given. In turn, firm I maximizes its profit anticipating firm E's reaction. The equilibrium firm E's quantities and market prices are

$$q_{SD}^{E} = \frac{a}{4}, \quad q_{AD}^{E} = \max\left[\frac{a-3\varepsilon}{4}, 0\right], \quad P_{SD} = \frac{a}{4}, \quad P_{AD} = \min\left[\frac{a+\varepsilon}{4}, \frac{a}{3}\right].$$

Then, condition (9) becomes

$$\eta > \max\left[\frac{10a-23\varepsilon}{12a-18\varepsilon}, \frac{7}{18}\right].$$

As under Cournot competition, there exists a level of η below which inequality (9) cannot be fulfilled. Since for $\varepsilon \geq a/3$ firm E's output is zero, this level is now $\eta = 7/18$. As ε decreases in the interval $0 < \varepsilon < a/3$, the ratio $(10a - 23\varepsilon)/(12a - 18\varepsilon)$ increases, until reaching the value $5/6$ at $\varepsilon = 0$. Thus, condition (9) turns out to be more likely fulfilled under Stackelberg than under Cournot competition (see the shaded zone in Figure 2). The reason for this is that in the ideal passage from Cournot to Stackelberg competition, for each $\varepsilon < a/3$ both the differences $\Delta_{AD} - \Delta_{SD}$ and $\pi^E_{SD} - \pi^E_{AD}$ decrease, but $\Delta_{AD} - \Delta_{SD}$ decreases more than $\pi^E_{SD} - \pi^E_{AD}$.[13]

• *Bertrand competition*. If the two firm compete in price, at the equilibrium we have $P_{SD} = 0$ and $P_{AD} = \varepsilon$, implying $\pi^E_{SD} = \pi^E_{AD} = 0$. Then, instead of the interior solution in equation (3), maximization of Π^E in equation (2) gives the corner solution $\gamma = 0$, which obviously renders minimization of SC with respect to γ a meaningless problem. Consequently, condition (9) also becomes meaningless: whatever the pair (η, ε), firm E's investment in duplication will be zero, that is social costs cannot be affected by the scope of trade secret law.

• *Collusion*. Antitrust notwithstanding, it may be that the two firms collude, in the sense that firm I pays firm E a fee, negatively related to the cost differential, and firm E stays out of the market. If this is a real possibility, a maximum scope of trade secret law turns out to be surely beneficial for society. In fact, since $P_{SD} = P_{AD} = P_M$ and $q^E_{AD} = 0$, condition (9) reduces to $\eta > 0$, that is, it is fulfilled for any relevant pair (η, ε).[14]

• *Incumbent's post-patent monopoly*. Until now we have assumed that $\varepsilon < a/2$. If $\varepsilon \geq a/2$ and firm E fails its duplication attempt, firm I continues to enjoy full monopoly power beyond the date of patent expiration. In this case, when the two firms compete à la

[13] Under Stackelberg competition there exists no $\varepsilon < a/3$ such that limit pricing is a privately superior alternative. This can be viewed by comparing the incumbent's profit flows under asymmetric-cost Stackelberg duopoly, given by $(a+\varepsilon)^2/8$, with the profit flow under limit pricing, that is $\varepsilon(a-\varepsilon)$. For $a/3 < \varepsilon < a/2$ limit pricing and Stackelberg solutions coincide.

[14] Note that under collusion π^E_{SD} and π^E_{AD} are given by the fees paid by firm I in the two situations.

Cournot if the duplication attempt succeeds, market prices and firm $E's$ outputs in condition (9) will be

$$q_{SD}^{E} = \frac{a}{3}, \quad q_{AD}^{E} = 0, \quad P_{SD} = \frac{a}{3}, \quad P_{AD} = P_M = \frac{a}{2}.$$

Then, condition (9) reduces to $\eta > 5/8$. When, instead, the incumbent can act as a Stackelberg quantity leader, we have

$$q_{SD}^{E} = \frac{a}{4}, \quad q_{AD}^{E} = 0, \quad P_{SD} = \frac{a}{4}, \quad P_{AD} = P_M = \frac{a}{2},$$

and condition (9) becomes $\eta > 3/2$, which cannot hold.[15] Summing up, when entry does not occur because of a cost differential greater than the monopoly price and η is constant, condition (9) can be fulfilled under potential Cournot competition but not if the incumbent firm is able to act as a Stackelberg leader.

3.3. The Elasticity of Duplication Probability

We have seen that under Cournot competition a necessary condition for inequality (9) to hold is $\eta > 5/8 = 0.625$. Likewise, under Stackelberg competition inequality (9) cannot be fulfilled if η does not exceed the value $7/8 = 0.388$. As there is no empirical evidence on the value of η –which measures the elasticity of individual probability of duplication success with respect to the individual expense for duplication– the only thing we can say is that likely it varies greatly according to the innovation type, in the same way as the elasticity of the supply of inventions –which can be viewed as the elasticity of the aggregate probability of invention success, empirically proxied by the number of patent applications, to aggregate research expenses– appears to vary greatly across sectors and

[15] See footnote 11 above.

over time (see Denicolò, 2007, and the literature cited therein).[16] Since something similar seems to hold for the cost differential ε, the only conclusion we can sensibly drawn is that there may exist particular market situations where a negative (positive) effect on social welfare of a reduction (an increase) in the scope of trade secret law cannot be excluded, despite the patent-secret holder is over-rewarded. Obviously, at the present no policy implication can be deducted, either for the aggregate or for specific sectors.

4. Conclusion

We presented a simple model in which a producer innovator owns a proprietary product protected by a mixture of patent and trade secret. An entrant tries to duplicate the secret part of the incumbent's technology, with a probability of success depending on the amount of resources devoted to this aim and on the quantity of usable knowledge spilled out of the incumbent firm, which in turn depends on the scope of trade secret law. At the patent expiration date, the competitor will enter the market at the same production cost as the incumbent if duplication is successful, or higher costs if the duplication attempt fails. We showed that in this context, under some conditions a broad scope of trade secret law is socially beneficial despite the innovator is over-rewarded.

For example, in a linear Cournot duopoly a strong trade secret protection turns out to be socially beneficial when the secret part of technology is rather relevant in terms of production costs and the probability of duplication success is sufficiently elastic with respect to the expenses for duplication This result holds for a wider constellation of parameters when the incumbent firm can act as a Stackelberg leader or adopts a limit pricing strategy or colludes with the entrant. In any case, a strong trade secret protection

[16] Available estimates of the elasticity of the supply of inventions range from about 0.3 to about 1, depending on data sets and estimation methods. This great variability of estimates just suggests that the true elasticity may vary across sectors and over time.

may be collectively efficient in that it allows society to save on duplication costs that would otherwise be borne by the entrant firm: such saving may be sufficient to more than compensate the relatively high expected present value of dead-weight losses associated with a low probability that the duplication attempt is successful.

Appendix

Differentiating equation (5) with respect to θ we have

$$\frac{dSC}{d\theta} = (1-T)\left(-\frac{\Delta_{AD} - \Delta_{SD}}{r}\frac{d\gamma}{d\theta} + \theta g'(\gamma)\frac{d\gamma}{d\theta} + \theta g(\gamma) \right).$$

By using equation (4) we can eliminate $d\gamma / d\theta$. Then, rearranging terms the above derivative becomes

$$\frac{dSC}{d\theta} = \frac{1-T}{g''(\gamma)}\left(\frac{\Delta_{AD} - \Delta_{SD}}{r\theta} g'(\gamma) - (g'(\gamma))^2 + g(\gamma)g''(\gamma) \right).$$

At this point it is easy to verify that $dSC / d\theta$ turns out to be negative if and only if

$$\frac{(g'(\gamma))^2 + g(\gamma)g''(\gamma)}{g'(\gamma)} > \frac{\Delta_{AD} - \Delta_{SD}}{r\theta},$$

that is, by using equation (3), if and only if

$$\frac{(g'(\gamma))^2 - g(\gamma)g''(\gamma)}{(g'(\gamma))^2} > \frac{\Delta_{AD} - \Delta_{SD}}{\pi^E_{SD} - \pi^E_{AD}},$$

which is inequality (7) in the proof of Proposition 1.

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