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Published version:

DOI:10.1016/j.irle.2011.07.002

International Review of Law and Economics (2011), 31, 4, 219-227
doi:10.1016/j.irle.2011.07.002.

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.

JEL classification: K2; O31; O34.
Keywords**:** Knowledge spillovers; Duplication costs; Non-competition covenants; Inevitable disclosure.

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We thank two anonymous referees for suggestions that greatly improved the paper. We are grateful also to seminar audiences at the ISLE conference in Florence, the ALEA conference in Princeton and the IIOC in Vancouver for helpful comments. Special thanks to Luigi Franzoni who pointed out a fatal error in the early draft of the paper. The usual caveat applies.

1. Introduction

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 several relevant contributions in the field, whose origins can be dated back to Nordhaus (1969),[2] the issue of the optimal strength of trade secret protection has been somehow neglected. 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.[3] 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". In a similar vein Risch (2007) maintains that "trade secrets are justified by the economic benefits that flow from their existence, most notably incentives for businesses to spend less money protecting secret information or attempting to appropriate secret information". According to both authors, 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.

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[1] In some papers the choice between patent and trade secret protection is explicitly addressed, but the strength of trade secret protection is treated as exogenous (e.g. Cugno and Ottoz, 2006, Denicolò and Franzoni, 2004, Denicolò and Franzoni, 2008, Gallini, 1992). For a discussion concerning the interplay between optimal patent and trade secret protection, see Erkal (2004). A general discussion on the reasons explaining why an innovator can prefer secret to patent protection can be found in Friedman, Landes, and Posner (1991).

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

[3] Friedman et al. (1991) had previously maintained that, since the law did not protect against the loss of trade secrets by accident or by reverse engineering, there was in a sense no law of trade secret as such, concluding that there were good economic reasons for this. See also Landes and Posner (2003).

The papers cited above prevalently refer to cases in which a proprietary innovation is protected by trade secret only.[4] However, in spite of the 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" (Garvey & Baluch, 2007).[5]

To illustrate how patent and secret can coexist we can assume, e.g. that at the time the patent was filed the incumbent firm disclosed the best mode for carrying out the invention; successively, the incumbent firm discovered a better best mode which could be kept 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. Anyway, as compared to the case where patents and trade secrets are mutually exclusive, the simultaneous utilization of the two protection tools raises a specific policy issue. To explain why, assume for simplicity a patent scope so broad as to make any non-infringing imitation impossible: then, if the innovator can chose to protect its proprietary product through patent or secret, but cannot combine the two forms of protection, the policy makers' problem consists in the first place in setting the duration of patent coverage and the scope of trade secret law inducing the innovator to choose the socially preferable form of protection, given the incentive to innovate. As Denicolò and Franzoni (2008) pointed out, under rather general assumptions the solution of this problem requires that patent length, relative to the strength of trade secret laws, be such that the innovator's choice falls on the patent itself. If, instead, the innovating technology can be protected jointly by patents and secrets and expected secrets' duration is longer than patents' life, policy makers have to solve a different problem. First of all, note

[4] In Risch (2010) patent–secret mixtures are considered.

[5] 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 (2007) and *Celeritas 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.

that if the innovator can enjoy full patent protection without disclosing all components of its proprietary knowledge, a lengthening in patent life would not bear any effect on disclosure decision: the innovator would, in fact, have nothing to gain and something to lose by increasing the level of disclosure. Then, the relevant issue becomes: given patent duration, what is the socially optimal scope of trade secret law for innovations covered by a patent–secret mix? Or, in other words, since innovations covered by a patent–secret mix enjoy the prospect of some protection even after the patent expiration – i.e. they are over protected with respect to comparable innovations covered by patents only – would society benefit from a low scope of trade secret law?

In this paper we attempt to face this issue using a model in which the social cost associated with the mixtures of patents and trade secrets includes, besides dead-weight losses and innovative R&D costs, 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 sustained by the two firms to protect or illicitly obtain information,[6] we focus on the relations between duplication costs (by legal means) and social welfare, along the lines of previous models present in the literature (Denicolò & Franzoni, 2008; Gallini, 1992; Maurer & Scotchmer, 2002). A special feature of our model is nevertheless the relation between duplication expenses, the probability of duplication success, and the scope of trade secret law.

By assuming 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. As we will see, in our model a broad scope of trade secret law enhances the probability that the innovation is achieved in the first place and permits society to save on wasteful duplication costs borne by a potential entrant: these benefits may more than compensate the reduction in the probability of competitive entry and the increase in the original innovator's expenses on R&D.

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.

[6] 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).

2. Employee mobility, knowledge spillover, and duplication costs

Apart from clearly illegal means for appropriating secret information, such as industrial espionage, employee mobility seems to be the main cause of technology spillovers among firms.[7] The model we will put forward in Section 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.

To the purpose of limiting such harmful losses, firms may, in fact, insert in employment contracts post-employment clauses, known as "post-employment covenants not to compete", or, in the absence of covenants, firms may still resort to a lawsuit by appealing to the "inevitable disclosure doctrine" or similar arguments. The scope of trade secret protection largely depends on the degree of jurisdictions' acceptance of these protection tools.

2.1. Labor mobility restrictions

Post-employment covenants consist of promises by employees not to work for a competitor for a specified period after employment ends. Enforceability of post employment covenants not to compete is provided for by the law in almost all US and EU jurisdictions, with the notable exception of California where covenants are banned.[8] Under California law employee mobility has, in fact, no limits, so that in our meaning the scope of trade secret law is at a minimum; elsewhere, covenants non to compete are enforceable if they respect some standards, according to which labor mobility is more or less facilitated.

[7] With reference to high technology districts see, e.g. Saxenian (1994), Gilson (1999), and Hyde (2003).

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

The differences in conditions for enforceability of such covenants mainly concern geographical and temporal restrictions, employees' financial compensations and employees' job positions. Typically, a non-competition agreement must restrict the employee's right to join a competing firm after the earlier employment relationship has been terminated for a time no longer than "necessary to protect the legitimate business interests of the employer", including trade secrets and other confidential information (*Marine Contractors Co.*, *Inc. v. Thomas F. Hurley*, 365 Mass. 280, 1974). As to financial compensation to the employee, they must be explicitly provided for in employment contracts, personal or collective, in almost all EU states, while other jurisdictions –notably, the overwhelming majority of states in the US, Norway, Switzerland, Iceland and, inside EU, Great Britain– do not require special consideration in labor contracts for worker's agreement to a non-competition covenant.[9] It is worthwhile noticing that the above standards limit the employers' ability to control labor mobility but, as Gilson (1999) and Hyde (2003) point out, enforcements of non-competition agreements still seem to make up a serious hindrance to knowledge spillover (see also Fudenberg & Tirole, 1983, p. 529).

Another typical standard, the application of which implies that a "strong" trade secret protection *per se* does not bar disclosure of even non-trade secret information, regards employees' job positions with respect to access to trade secrets. In principle, according to such standard, a skilled employee who possesses valuable non-confidential knowledge may join a competing firm without incurring the risk of being blocked by an injunction. It might appear that in the Silicon Valley case, analyzed by Gilson (1999) and Hyde (2003), general knowledge could not be separated from information eligible for trade secrets protection, so that enforcing covenants not to compete would inevitably correspond to barring all employees from changing workplace.[10] Nevertheless, this is not the position adopted by Massachusetts

[9] Source http://www.ilo.org/public/english/dialogue/ifpdial/downloads/judges06/nc.pdf.

[10] We have to recognize that because of in terrorem effect of law employee mobility can be barred by the intimidation of contractual restrictions whose severity no court would sanction (Blake, 1960). In such cases, we can consider the law to be strong even if courts would not enforce some kind of post-employment covenants. It appears likely enough, however, that in terrorem effect will be the more effective the more courts are inclined to enforce covenants containing severe restrictions.

representatives William Brownsberger and Lori Ehrlich who, having in mind the downturn of the Route 128 area and the relative success of the Silicon Valley area, initially submitted two bills, one of which would ban non-competes altogether, whereas the other would allow the enforcement of reasonably tailored agreements. Successively they worked on a compromise bill which "bans non-competes for employees paid less than $100,000 annually, but allows non-competes for employees making between $50,000 and $100,000 if the agreement is necessary to protect trade secrets or confidential information" (Perrelli, 2009). Moreover, apart from high technology districts, in many productive sectors the overwhelming majority of skilled employees possesses worthwhile knowledge without having access to trade secrets, so that a broad scope of trade secret law, although minimizing the diffusion of confidential information, *per se* would have relatively little effect on the overall labor mobility and, consequently, on knowledge spillover of non-trade secret information.[11]

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 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" (Paetkau, 2003), 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.

Anyway, where the inevitable disclosure doctrine –or some equivalent argument– is adopted, the scope of trade secret law tends to be broader than elsewhere. In

[11] Obviously, problems would arise when an employer views as a trade secret what the departing employee claims to be his general skills (Risch, 2010). Typically, these disputes must be resolved in courts.

PepsiCo., *Inc*. *v*. *Redmond* the court, applying the inevitable disclosure doctrine, analogized PepsiCo's position, with respect to a former employee who was about to be hired by a competitor (Quaker), as similar to that of "a coach who had lost a valuable player to the opposing team, playbook in hand, on the night before a decisive game. Accordingly, it affirmed the district court order enjoining Redmond from assuming his position at Quaker and preventing him forever from disclosing PepsiCo trade secrets and confidential information" (Kaplan & Hanlon, 2004).

The adoption of inevitable disclosure doctrine is typical of several, but not all, US 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 sign 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".

2.2. The model

First, let us distinguish between pre- and post-innovation stages. In the post innovation stage, a firm, labeled I (innovator/incumbent), owns a proprietary product jointly protected by patents, whose normalized length is T,[12] and trade secrets, which have no fixed expiration date.[13] Patents are assumed to be broad enough to make any non-infringing imitation impossible, so that competitors cannot enter the market before patent's expiration – i.e. we assume that the disclosed part of the technology is

[12] Given a patent life of t years, the normalized length is defined as $T = 1 - e^{-rt,}$ where r is the discount rate.

[13] 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).

protected by ironclad patens, and no imitating product can be obtained without it. As a consequence of this assumption the overall strength of patent protection is fully captured by patent's life. At the patent expiration date a new firm, called firm *E* (entrant), is founded. This new-generation firm will attempt to duplicate the secret information by spending resources at this aim: it will 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.

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.[14] 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 how easily firm *I*'s employees can join the new generation firm. 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 US) or similar legal arguments.

By utilizing the set of information obtained through employee mobility, at time T firm *E* will spend resources to duplicate all components of firm *I*'s technology protected by trade secret. Given the sum spent for duplication, called K^E, the probability of success, γ, will increase with the size of the set of disposable information, which in turn diminishes as the scope of trade secret law increases. In what follows, for sake of simplicity the scope of trade secret law is treated as a continuous variable depending on the conditions required by the relevant courts for enforcing post-employment covenants or applying the inevitable disclosure doctrine.

Summing up, the foregoing outline suggests a simple game with two players: firm *I* (innovator/incumbent) and firm *E* (entrant). The game is non-cooperative and consists of two stages: pre- and post-innovations.

In the pre-innovation stage firm *I* plans its R&D effort in order to obtain the optimal value of its choice variable, the probability of success β, so as to maximize

[14] Fragmentation of secret information is a common defensive practice. It is the most prominent example of what Risch (2007) refers to as a "non-standard precautionary measure".

the expected profit flows deriving from a proprietary innovation whose technology consists of at least two components, one of which is patented while the other is kept secret.

In the post-innovation stage, at the time firm *I* experiences patent expiration, firm *E* will attempt to enter the market by duplicating the secret information spending resources at this aim. It will enter the market bearing the same production costs of firm *I* if duplication is successful, or higher costs if the duplication attempt fails, giving rise to symmetric duopoly in the first case and to a asymmetric duopoly in the second case. The choice variable of firm *E* is the privately optimal value of γ, the probability of duplication success, dependent on the resources spent for duplication, given of trade secret protection strength.

The relevant solution concept is subgame perfection. As it is customary in such case, we work backwards from the last stage of the game to the first.

2.2.1. Post-innovation stage

By adopting the usual convexity hypothesis, we assume that firm *E* faces a cost function relating the probability of duplication success γ to the duplication effort K^E of the kind

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

where $g(0) = 0$, $g'(\gamma) > 0$, $g''(\gamma) > 0$ and the shift parameter $\theta > 0$ 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 (1998) 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^E_{SD}. If the attempt fails, firm *E* may enter the market with a production cost associated with the information disclosed in the patent application, i.e. with higher costs than firm *I*.[15] In this case firm *E* will gain a stream of asymmetric-cost profits $0 < \pi^E_{AD} < \pi^E_{SD}$. Given that *r* represents the discount rate, firm *E* will then choose γ by maximizing the expected rent

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

If an interior solution exists, the privately optimal value of γ will be determined by

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

from which

$$\frac{d\gamma}{d\theta} = \frac{\pi^E_{SD} - \pi^E_{AD}}{g''(\gamma) r\theta^2} = \frac{g'(\gamma)}{g''(\gamma)\theta} < 0 . \tag{4}$$

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

2.2.2. Pre-innovation stage

Let us now go backward to the pre-innovation stage. In analogy with the cost function (1), suppose that the innovation effort, K^I, and the probability of success, β, are linked by the relation $K^I = f(\beta)$, where $f(0) = 0$, $f'(\beta) > 0$, $f''(\beta) > 0$. Moreover, suppose that when planning R&D expenses the innovator expects that –provided the innovation attempt succeeds– with probability *q* some relevant pieces of the technology to be discovered can be kept undisclosed without incurring the risk of losing patents' protection on the whole proprietary product. This means that the probability the innovator assigns to the event of enjoying a cost advantage after patent

[15] This modelling strategy is well suited to the case where, after obtaining a patent on a product innovation, firm *I* discovers a better best mode which can be kept secret. As many practitioners maintain, this is a very common occurrence (Jorda, 2007). More generally, we can think of the term "cost advantage" as a proxy for "competitive advantage" which the incumbent can enjoy by keeping secret "specialized processes, customer lists, business plans, and other information integral to the firm" (Burk & McDonald, 2007).

expiration if the innovation is achieved amounts to $q(1-\gamma)$.[16] Then, if π^I_{AD} and π^I_{SD}, with $\pi^I_{AD} > \pi^I_{SD}$, stand for the innovator's profit flows under asymmetric and symmetric-cost duopoly, respectively, while π_M is the monopoly profit flow, the innovator's expected rent will be

$$R^I = \beta\left(T\frac{\pi_M}{r} + (1-T)\frac{q(1-\gamma)\pi^I_{AD} + [1-q(1-\gamma)]\pi^I_{SD}}{r}\right) - f(\beta)\,. \tag{5}$$

If R^I has an interior maximum, the privately optimal value of β will be determined by

$$f'(\beta) = T\frac{\pi_M}{r} + (1-T)\frac{q(1-\gamma)\pi^I_{AD} + [1-q(1-\gamma)]\pi^I_{SD}}{r}\,, \tag{6}$$

from which

$$\frac{d\beta}{d\theta} = \frac{(1-T)q(\pi^I_{AD} - \pi^I_{SD})}{rf''(\beta)}\frac{d\gamma}{d\theta}\,. \tag{7}$$

Since $\pi^I_{AD} > \pi^I_{SD}$, $f'(\beta) > 0$, and, from Eq. (4), $d\gamma/d\theta < 0$, it follows that $d\beta/d\theta \geq 0$ according to $q \geq 0$. If the probability of concealability q is positive an increase in the scope of trade secret law enhances the incentive to innovate. In what follows we determine conditions under which this is associated with social welfare improvements.

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

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[16] We have to distinguish the probability of concealability q from trade secret law. In our framework the probability of concealability depends essentially on technological features, although it can be affected by patent law requirements on written description, enablement and best mode. The joint probability that in the patent application the innovator can conceal some pieces of technology and the entrant will not be able to duplicate them at the patent expiration, $q(1-\gamma)$, depends instead on trade secret law through the effects on the probability of duplication success γ.

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 us 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. The post-innovation expected social cost, SC, is the sum of the expected present value of dead-weight losses and of the present value of the cost borne by firm E to duplicate the secret. Then,

$$SC = T\frac{\Delta_M}{r} + (1-T)\left(\frac{\gamma\Delta_{SD} + (1-\gamma)\Delta_{AD}}{r} + \theta g(\gamma)\right), \tag{8}$$

so that the present value of expected social welfare turns out to be

$$SW = \beta(\overline{SW} - SC) - f(\beta). \tag{9}$$

where $\overline{SW}$ stands for the present value of social welfare that would prevail under perfect competition.[17]

Maximizing SW with respect to θ and T, under the constraints that the innovator and the duplicator choose R&D and duplication expenses in the privately optimal ways described above, we in general can determine the socially optimal combination

[17] Uncertainty related to duplication success is the only kind of uncertainty relevant in the definition of post-innovation social costs SC. Thus, the parameter q does not appear explicitly in the definition of expected pre-innovation social welfare $\beta(\overline{SW} - SC) - f(\beta)$. Nevertheless, uncertainty related to concealability affects the expected pre-innovation social welfare through the parameter β (Eq. (6)). As Proposition 1 below will show, our result will hold for all $q \in (0, 1]$.

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 by patents only, may be that policy makers wish to fix T in order not to penalize this second type of innovations. If so, the problem becomes that of verifying if a reduction in the scope of trade secret law, facilitating in prospect competitive entry, enhances social welfare. Proposition 1 below shows that under certain conditions the opposite happens.

Proposition 1. Define the elasticity of probability of firm E's duplication success with respect to the expense for duplication as $\eta = (d\gamma / dK^E)(K^E / \gamma) = g(\gamma) / g'(\gamma)\gamma$. Then, the inequality

$$\eta + \frac{d\eta}{d\gamma}\gamma > \frac{\Delta_{AD} - \Delta_{SD}}{\pi^E_{SD} - \pi^E_{AD}} \quad \text{for all } 0 < \gamma < 1, \tag{10}$$

is a sufficient condition for expected social welfare SW to be monotonically increasing in the scope of trade secret law for all $0 < q \leq 1$ and $0 < T < 1$.

Proof. First we show that condition (10) is sufficient and necessary for post innovation expected social cost SC to be monotonically decreasing in the scope of trade secret law. Using Eqs. (3), (4), (8) we can verify that if

$$\frac{(g'(\gamma))^2 - g(\gamma)g''(\gamma)}{(g'(\gamma))^2} > \frac{\Delta_{AD} - \Delta_{SD}}{\pi^E_{SD} - \pi^E_{AD}}, \tag{11}$$

then $dSC/d\theta < 0$. (See Appendix for details.) On the other hand, differentiating $\eta = g(\gamma) / g'(\gamma)\gamma$ and rearranging terms, we have

$$\frac{(g'(\gamma))^2 - g(\gamma)g''(\gamma)}{(g'(\gamma))^2} = \eta + \frac{d\eta}{d\gamma}\gamma. \tag{12}$$

Thus, inequality (11) corresponds to inequality (10).

Let us now consider expected social welfare SW. Differentiating Eq. (9) we have

$$\frac{dSW}{d\theta} = -\beta\frac{dSC}{d\theta} + (\overline{SW} - SC - f'(\beta))\frac{d\beta}{d\theta}. \tag{13}$$

Using again Eq. (9), $\overline{SW} - SC = (SW + f(\beta))/\beta$, and, from Eqs. (5), (6), $f'(\beta) = (R^I + f(\beta))/\beta$. Then, Eq. (13) can be written

$$\frac{dSW}{d\theta} = -\beta\frac{dSC}{d\theta} + \frac{SW - R^I}{\beta}\frac{d\beta}{d\theta}. \tag{14}$$

The statement in Proposition 1 follows from the facts that: (i) the difference $SW - R^I$ is positive (besides the expected innovator's rent, expected social welfare includes the expected entrant's rent and consumer surplus); (ii) the derivative $d\beta/d\theta$ is positive for all $0 < q \leq 1$ and $0 < T < 1$ (see Eq. (7)); and (iii) under condition (10) the derivative $dSC/d\theta$ is negative (Eqs. (11), (12)). ■

The rationale of Proposition 1 is that when condition (10) holds a broad scope of trade secret law benefits society through both a low level of post-innovation social costs SC and a high level of β.[18] In fact, a high legal protection of trade secret allows society to save on duplication costs that would be otherwise borne by firm E : under condition (10) this saving is 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. Moreover, since the original innovator expects that some relevant pieces of the technology to be discovered will be concealable, by enhancing the innovator's expected rent a broadening in the scope of trade secret law increases R&D expenses, which in turn positively affect the probability of success β. In terms of social welfare, the positive effect on β overweighs the negative one on costs.[19]

[18] Since Proposition 1 establishes a sufficient, not necessary, condition on the elasticity η, under some circumstances society may benefit from a broad scope of trade secret law even if the inequality (10) is reversed. Unfortunately, by rendering explicit the necessary and sufficient condition $-\beta(dSC/d\theta) + (1/\beta)(SW - R^I)(d\beta/d\theta) > 0$ in terms of all set of parameters and functions we obtain a formula whose economic meaning is hard to understand. So, we have to be content with the sufficient condition (10).

[19] Although it may seem odd that strengthening trade secret law is more likely to benefit society for high levels of the elasticity η, i.e. when at the margin duplication expenses are more likely to involve reductions in the present value of expected deadweight losses, the

It is worthwhile noticing that the hypotheses we have formulated on the relation between γ, k and θ are crucial for our 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 (Denicolò & Franzoni, 2008). In these circumstances, if the probability of total leakage is negatively affected by the scope of trade secret law, from the post-innovation point of view 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, which guarantees the maximum of competition.

Something similar holds for spillover theory such as proposed in Hyde (2003). This theory seems based on the assumptions that social welfare is maximized through competition and duplication costs are minimized with leakage. Hyde's starting point, therefore, appears to be that competitors try to duplicate anyhow and spillovers reduces duplication costs, which leads to the recommendation of a minimum scope of trade secret law.[20]

Our model differs from the above formulations as it assumes that: (1) without knowledge spillovers the probability of duplication success is low, implying a weak incentive to spent in duplication; (2) by fragmenting secret information, the original innovator suffers only partial spillovers; and (3) partial spillovers increase the probability of duplication success, which enhances the incentive to spent in duplication. Then, the status quo with a broad scope of trade secret law is not "high expenses in duplication" – the incentive to duplicate is weak. Moreover, since the productivity of duplication expenses in terms of probability of success increases at the margin with the size of spillovers, as we have seen post-innovation social cost may increase when the scope of trade secret law is narrowed.

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reason stays on the incentive effects of high levels of this elasticity. In fact, it is precisely a high marginal (expected) productivity of duplication expenses in terms of the probability γ that may create incentives to invest in duplication too strong from a social point of view. In other words, for η high and θ low private optimality implies investments in duplication too high relative to the expected benefits from duplication.

[20] An anonymous referee suggested us this interpretation.

Finally, let us spent some words on the role of patent duration T. In our framework T affects social welfare $\beta(\overline{SW} - SC) - f(\beta)$ through both the probability of innovation success β and post-innovation social costs SC. Since SC depends on T with uncertain sign (see Eq. (8)), the overall effect of a change of patent duration cannot be forecast without further specifications. One thing we can say is that if trade secret law is strong, maybe we are better off with short patent terms because of a low level of expected duplication costs.

3.2. Reverse engineering, protection costs, and rent dissipation

In Samuelson and Scotchmer (2002) the authors argument that “When a particular means of reverse engineering makes competitive copying too cheap, easy, or rapid, innovators may be unable to recoup R&D expenses. If so, it may be reasonable to regulate that means. Anti-plug-mold laws … are an example. Using a competitor's product as a “plug” to make a mold from which to make competing products, allows competitive copying that is so cheap and fast that it undermines the incentives to invest in designing an innovative product. Restrictions on plug-molding may restore adequate incentives to make such investments”. Provided that the cost of reverse engineering is high enough, according to the authors the innovator can prevent it entirely, especially if a licensing strategy for avoiding unlicensed entry is adopted. In this case, licensing will permit the innovator to recoup its R&D expenses, while at the same time constraining the exercise of market power in order to dissuade other potential entrants: as a consequence, society saves on wasteful duplication costs.

Since regulation of reverse engineering can be viewed as equivalent to a broadening in the scope of trade secret law, our result partially parallels the above arguments. We show, however, that society can gain from making duplication more difficult even when, due to high transaction costs, licensing is not an option. Note, moreover, that these social gains are independent on any possible reduction in innovator's expenses to protect against misappropriation, caused by a broadening of trade secret law. If we were considering the arguments put forth by Risch (2007) and Lemley (2008), that information-owners’ expenses to prevent illegal appropriation efforts diminish, as the strength of legal trade-secret protection increases, our result would be reinforced as the range over which a broad scope of trade secret law is efficient would be expanded.

Finally, note that in terms of the rent dissipation theory our result can be read as follows: at the patent expiration date, duplicator's entry implies a decrease in producer surplus (because joint duopoly profits are less than monopoly profits) and an increase in consumer surplus. Moreover, the entrant firm will spend some money in attempting duplication of trade-secrets. Thus, if the sum of duplication expenses plus the reduction in joint profits outweighs the increase in consumer surplus, at the social level we have a (partial) post-invention rent dissipation − the second type of rent dissipation envisaged by Grady and Alexander (1992). Under condition (10) in Proposition 1, this type of rent dissipation is minimized when the scope of trade secret law is at a maximum.

3.3. Some special cases

To gain more insights into the meaning and relevance of condition (10) in Proposition 1 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 producing at constant marginal costs equal to zero, the inferior technology implies a constant cost disadvantage equal to ε.[21] Under the above linearity assumptions and the additional hypothesis that the function $g(\gamma)$ is iso-elastic ($d\eta/d\gamma = 0$), condition (10) can be written

$$\eta > \frac{\Delta_{AD} - \Delta_{SD}}{\pi_{SD}^{E} - \pi_{AD}^{E}} = \frac{(1/2)(P_{AD})^2 + \varepsilon q_{AD}^{E} - (1/2)(P_{SD})^2}{P_{SD} q_{SD}^{E} - (P_{AD} - \varepsilon) q_{AD}^{E}}, \tag{15}$$

[21] 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.

where q_i^E, i = SD, AD, stands for firm E's output.[22] In what follows we will examine Cournot competition (integrated with limit pricing), Stackelberg competition with the incumbent firm acting as the quantity leader, 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 (10) in Proposition 1 is fulfilled.

3.3.1. 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 $q_{SD}^E = a/3$, $q_{AD}^E = (a-2\varepsilon)/3$, $P_{SD} = a/3$, $P_{AD} = (a+\varepsilon)/3$. Then, condition (15) 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 (15) to be satisfied is η > 5/8.

For η > 5/8 inequality (15) can be fulfilled provided that ε is sufficiently high (see the shaded zone in Fig. 1, panel i).[23] 23 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, i.e. 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 society to save

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

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

resources, whose amount exceeds the expected present value of dead-weight losses associated with no duplication.

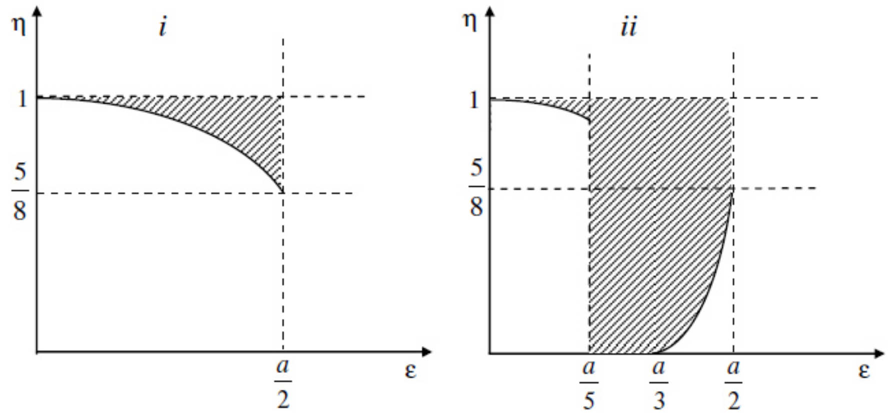

Fig. 1: Condition (15) under Cournot competition (panel i) and limit pricing (panel ii).

3.3.2. 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, i.e. 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 pricing turns out to be a superior alternative for the incumbent if $a/5 < \varepsilon < a/2$.[24] 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 $q^E_{SD} = a/3$, $q^E_{AD} = 0$, $P_{SD} = a/3$, $P_{AD} = \varepsilon$, while for $\varepsilon < a/5$ the results for Cournot competition hold, condition (15) becomes

[24] 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 $a/5 < \varepsilon < a/2$.

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

Contrary to what happens in the case illustrated in panel i of Fig. 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^E_{AD} 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 (15) to be fulfilled (see the shaded zone in Fig. 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 saving duplication expenses, turns out to be beneficial for society.

3.3.3. 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 $q^E_{SD} = a/4$, $q^E_{AD} = \max[(a-3\varepsilon)/a, 0]$, $P_{SD} = a/4$, $P_{AD} = \min[(a+\varepsilon)/4, a/3]$. Then, condition (15) 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 (15) cannot be fulfilled. Since for $\varepsilon \geq a/3$ firm E's output is zero, this level is now η = 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 (15) turns out to be more likely fulfilled under Stackelberg than under Cournot competition (see the shaded zone in Fig. 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 $\pi^E_{SD} - \pi^E_{AD}$.[25]

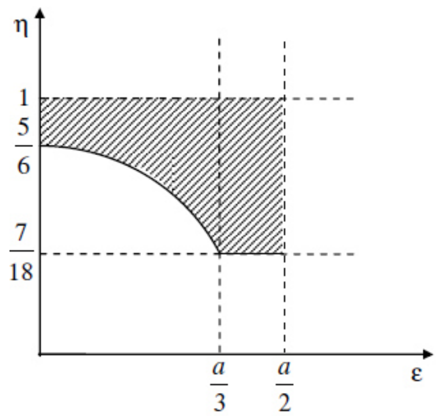

Fig. 2: Condition (15) under Stackelberg competition.

3.3.4. 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, condition (15) is surely respected: in fact, since $P_{SD} = P_{AD} = P_M$ and $q^E_{AD} = 0$, condition (15) reduces to $\eta > 0$, i.e. it is fulfilled for any relevant pair (η, ε).[26]

3.3.5. Incumbent's post-patent monopoly

So far 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 Cournot, if the duplication attempt succeeds, market prices and firm *E*'s outputs in condition (15) will be $q^E_{SD} = a/3$, $q^E_{AD} = 0$, $P_{SD} = a/3$, $P_{AD} = P_M = a/2$: then, condition (15) reduces to $\eta >$

[25] 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, i.e. $\varepsilon (a - \varepsilon)$. For $a/3 < \varepsilon < a/2$ limit pricing and Stackelberg solutions coincide.

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

5/8. When, instead, the incumbent can act as a Stackelberg quantity leader, we have $q_{SD}^E = a/4$, $q_{AD}^E = 0$, $P_{SD} = a/4$, $P_{AD} = P_M = a/2$, and condition (15) becomes $\eta > 3/2$, which cannot hold.[27] Summing up, when entry does not occur because of a cost differential greater than the monopoly price and if η is constant, condition (15) can be fulfilled under potential Cournot competition, but not if the incumbent firm is able to act as a Stackelberg leader.

3.4. The elasticity of duplication probability

We have seen that under Cournot competition a necessary condition for inequality (15) to hold is $\eta > 5/8 = 0.625$. Likewise, under Stackelberg competition inequality (15) cannot be fulfilled if η does not exceed the value $7/18 = 0.388$. 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 it is likely to vary 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, with respect to aggregate research expenses– appears to vary greatly across sectors and over time (see Denicolò, 2007, and the literature cited therein).[28] Since something similar seems to hold for the cost differential ε, the only conclusion we can sensibly draw is that there may exist particular market situations where fulfillment of condition (15) cannot be excluded. Obviously, at present no policy implication can be deducted, either for the aggregate or for specific sectors.

4. Conclusions

We presented a simple model in which an incumbent firm owns a proprietary product protected by a mixture of patents and trade secrets. At the patents' expiration date an entrant tries to duplicate the secret part of the incumbent's technology, with a

[27] See footnote 23 above.

[28] 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.

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. Then, the competitor will enter the market at the same production cost as the incumbent if duplication is successful or at higher costs if the duplication attempt fails. We showed that in this context, under some conditions a broad scope of trade secret law may be socially beneficial, either if the innovator, when deciding R&D expenses, anticipates that some pieces of the technology to be discovered will be concealable, or if concealability becomes amserendipitous opportunity after the innovation has been achieved.

For example, in a linear Cournot duopoly a sufficient condition, for a strong trade secret protection to be socially beneficial, is that 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 range of parameters when the incumbent firm acts as a Stackelberg leader or adopts a limit pricing strategy or colludes with the entrant. In any case, independently on the innovator's forecasting ability, a strong trade secret protection 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 Eq. (8) we have

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

i.e. using Eq. (4) to eliminate $d\gamma/d\theta$ and rearranging terms,

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

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

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

i.e. using Eq. (3), if and only if

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

which is inequality (11) in the proof of Proposition 1.

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