Patents, Secrets, and the First Inventor Defense

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Abstract

We analyze optimal patent design when innovators can rely on secrecy to protect their innovations. Secrecy provides a temporary monopoly, which terminates when the secret leaks out or the innovation is duplicated. We find conditions under which the optimal policy is to induce the first innovator to patent. Furthermore, we derive the optimal scope of the rights conferred to late innovators. We show that if the patent life can be suitably set, broad patent protection is optimal: late innovators should be allowed to patent and exclude first inventors who have relied on secrecy.

JEL Nos: K11 (Property law), O34 (Intellectual property rights), L00 (Industrial organization).

Keywords: patents, trade secrets, intellectual property.

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1 Introduction

Trade secrets and patents are both legal means of protecting an innovator's proprietary knowledge.[1] Although the patent system prohibits certain industries from seeking patent protection, and secrecy is infeasible in others, many inventors can choose between these forms of protection. The fact that secrecy represents an available option for innovators has non-obvious implications for patent design.

This paper has two main objectives. The first, more specialized objective is to analyze the optimal scope of the rights to be assigned to the second inventor when the first inventor opts for secrecy and the innovation is independently rediscovered. Should the second inventor be entitled to a valid patent?[2] If yes, should the second-inventor patentee be allowed to exclude the first inventor from the innovation, or should the first inventor be granted a defense to infringement (i.e. a prior user right)?

Notable differences in the breadth of the legal rights assigned to second-inventors are observable from nation to nation and over time. For instance, under the British 1956 Patent Act second inventors were not entitled to valid patents. In most European countries, second inventors can patent, and first inventors retain prior user rights. In the US, second-inventors' patents are held valid by the courts only in certain cases, and first inventors have no prior user rights. However, bills introducing a defense to infringement to first inventors have been repeatedly put on the floor in the Congress over the last decade.

The second broader objective of the paper is to ask whether society should en-

[1] In the landmark case *Kewanee v. Bicron* (416 US 470, 1974), the Supreme Court stated that the Patent Act does not preempt (state) trade secret laws. In subsequent analysis, the Court restricted this conclusion to those cases where the trade secret is put to public use (Brownlee, 1990).

[2] Of course, the Patent Office may not be aware that the innovation had been secreted by the first inventor when granting a patent to the second inventor, but such a patent may be subsequently invalidated by the courts.

courage patenting and disclosure instead of secrecy. The importance of secrecy as a tool for the protection of intellectual property is confirmed by extensive empirical evidence. Based on a survey questionnaire administered to 1478 R&D labs, Cohen, Nelson and Walsh (2000) report that "secrecy" and "lead time" are ranked as the most effective protection mechanisms for both product and process innovations.[3] Furthermore, secrecy is found to have increased in importance over the last decade, despite the apparent strengthening of the patent system. It is therefore important to gain a better understanding of the social costs of secrecy and the way in which they compare to those associated with patents.

To analyze these policy issues, we develop a simple model with an innovation stage and a duplication stage. In the innovation stage, the innovator chooses her R&D effort and which type of proprietary protection to adopt. In the duplication stage, a follower decides how much effort to devote to the "catching-up" and which type of proprietary protection to adopt upon successful duplication.

Patent policy influences the research efforts and the patenting decisions of both the innovator and the duplicator. The policy variables that we focus on are the patent length, taken as a comprehensive index of the strength of patent protection, and the scope of the rights assigned to the second inventor.

Our main results are as follows. First, we show that a patent system where the second inventor can patent but the first inventor maintains prior user rights is equivalent to a system where the follower cannot patent at all (Proposition 1). Second, denying prior user rights reduces the incentives to innovate but makes the first inventor more keen on patenting. As it turns out, this implies that any outcome obtained in a system with user rights can be replicated by a system without user rights and a suitable patent life (Proposition 2). Moreover, in the absence of user rights

[3] Similar findings emerge from prior empirical investigations. See, among others, Mansfield (1985) and (1986), and Levin, Klevorick, Nelson, and Winter (1987).

disclosure can be obtained with a shorter patent. Thus, whenever society prefers that the first inventor patents, it can achieve this goal with a smaller deadweight loss.

It is then natural to ask whether it is, indeed, socially desirable to induce the first inventor to patent, i.e. whether patents are socially superior to secrets. We address this issue in two steps. First, we pose the question whether a patent should be granted with the sole aim of inducing the disclosure of an innovation that has already been obtained. Such is the tenet of the "contract theory" of patents, which views patents as contracts whereby innovators obtain monopoly in exchange for disclosure.[4] Under plausible conditions, we vindicate the contract theory by finding that the *ex-post* optimal policy is, indeed, to induce the first inventor to patent (Propositions 3 and 4).

Next, we take into account the effects of patent policy on innovation effort. Surprisingly, even when patent protection is strong enough to induce the first inventor to patent, the incentive to innovate may be greater with secrets than with patents. As a consequence, it is optimal to have first inventors patent under more stringent conditions than in the *ex-post* analysis (Proposition 5).

Although the issue of prior user rights and the contract theory of patents are lively debated in the law literature, most of the economic literature assumes that innovators have no alternative to patenting. There are, however, a few notable exceptions. Horstmann, MacDonald, and Slivinski (1985) analyze the choice between patents and secrets in a signalling model where the innovator is better informed than its

[4] The "contract theory" is customarily adopted by the courts, along with the "reward theory," to justify the patent system. In *Universal Oil Products v. Globe Oil & Refining* (1944), for instance, the Supreme Court couched the view that: "As a reward for inventions and to encourage their disclosure, the United States offers a seventeen-year monopoly to an inventor who refrains from keeping his invention a trade secret. But the quid pro quo is disclosure of a process or device in sufficient detail to enable one skilled in the art to practice the invention once the period of the monopoly has expired; and the same precision of disclosure is likewise essential to warn the industry concerned of the precise scope of the monopoly asserted." See Eisenberg (1989) for an accurate overview of current legal theories and Machlup (1968) for an historical perspective.

potential competitor on the profitability of imitation or duplication. They model information transmission as a binary choice. Anton and Yao (1999, 2000) study strategic disclosure of knowledge in patent applications in the presence of limited patent protection, and find that in equilibrium small inventions are fully disclosed whereas large innovations are protected primarily through secrecy. As the innovator has private information about the size of the innovation, a partial disclosure can be used to signal the innovator's strength to his competitors. These papers do not focus on optimal patent policy.

Green and Scotchmer (1990) analyze a two-stage model of R&D in which, by patenting an intermediate result, a firm gains interim profits but helps its rival achieve the final innovation. Licensing agreements in a similar framework are analyzed by Battacharya, d'Aspremont and Gerard-Varet (2000). Also related is the work of La Manna, MacLeod, and De Meza (1989) and Maurer and Scotchmer (1999), who ask whether independent re-discoverers should be allowed to use the innovation, but posit that the first inventor always patents. Thus, they focus on the implications of the patentee's right to exclude "subsequent" rather than "prior" inventors.

Gallini (1992) analyses the optimal patent length and breadth with respect to imitators assuming that imitation occurs only if the innovator patents and the new technology is disclosed. Thus, while competing firms can "invent around" the patent, they cannot duplicate the innovation if it is not disclosed in the patent application. She does not address the issue of prior user rights, and focuses on the optimal breadth-length mix to protect the first innovator.

The paper is organized as follows. In Section 2, we review the patent law relevant to our analysis. In Section 3, we outline the game and solve it. Section 4 considers the optimal policy for the diffusion of the innovation, while Section 5 considers the optimal policy for both creation and diffusion. Section 6 concludes the paper.

2 Legal Background

While patents and trade secrets are deemed equally legitimate by the law, innovators cannot benefit from both. If they choose to patent, patent law requires them to disclose the innovation fully in the patent specification, so as to enable any person expert in the art to practice it.[5] This prevents them from extending the monopoly beyond the term of the patent. Alternatively, if they decide to rely on secrecy, they forfeit the right to patent after a one-year grace period. (Not even this one-year grace period is granted in Europe.) This prevents inventors from keeping the innovation secret and applying for a patent only under the threat of impending duplication.

The issue is more complicated when a secreted invention is independently rediscovered. Under 35 U.S.C. § 102(g), an inventor is entitled to a patent unless "before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it." This means that the second inventor may obtain a valid patent (within one year of his discovery) if the first inventor has abandoned, suppressed, or concealed her innovation. At this point the primary question becomes whether commercial use under the protection conferred by secrecy counts as a form of concealment, in which case the secreted invention does not constitute prior art.

In *Gore v. Garlock* (721 F.2d 1540, 1983), the court held that the prior user's secret use of a process to create a product (PTFE filament) did not invalidate the patent, despite the fact that the product had been commercially exploited (Brownlee 1990). Similarly, in a leading example of "non-informing public use," *Gillman v. Stern* (114 F.2d 28, 1940), the court held that a completed invention will be deemed

[5] See Friedman, Landes and Posner (1991), and Merges (1997). Sometimes, however, firms try and disclose the innovation only partially. For example, a complex innovation may have several components, some of which are patented while others are kept secret. See Anton and Yao (1999, 2000) for a more detailed discussion of incomplete disclosure of technical knowledge in patent applications.

"abandoned, suppressed or concealed" if no steps are taken to make it publicly known within a reasonable time. In this case, only the output of the machine was offered for sale; the machine itself (a pneumatic puffing machine for quilting) "was always kept as strictly secret as possible, consistently with its exploitation." The court held that such secret invention could not be prior art and did not invalidate the second inventor's patent (Merges 1997).

In other cases involving so-called "hidden public use" courts have reached the opposite conclusion. An example is *Dunlop v. Ram* (524 F.2d 33, 1975), wherein the court invalidated the patent filed by a subsequent inventor on the grounds that the product (a strong golf ball covering) had been earlier distributed to the public. Although preparation and material were not discernible from the balls, the court held that the invention had not been concealed.

The difference between the two types of public use seems to lie in the fact that the "hidden use" is hidden only because of the nature of the invention, and not because of any intentional concealment by the inventor (Merges 1997). It is unclear whether this distinction has important economic implications. The bottom line is that second-inventors' patents may or may not be valid in the US, depending on the circumstances.

Assuming that the second inventor is entitled to a valid patent, is the first (secret) user allowed to continue his activity? In most European countries and Japan, good faith prior use represents a defense from infringement. By way of contrast, currently in the US a valid patent grants the right to exclude the first inventor. This particular feature of the US patent law is presently under review, and in November 1999 a first inventor defense limitedly to business methods was introduced (*American Inventors Protection Act*).

To summarize these legal differences, assuming that the first inventor has elected to keep her invention a secret, we can identify three main policy options:

1. the second inventor cannot patent;
2. the second inventor can patent, but cannot exclude the prior user;
3. the second inventor can patent and can exclude the prior user.

The first option reserves the privileges accorded by the patent system for the first inventor alone. In the US, this option applies to "hidden public use" cases. It was also the rule in the UK prior to 1977, when it was changed to harmonize the British with the European patent law. The second option provides a defense to infringement to good faith prior users. Such a solution is present in most countries (WIPO 1988).[6] Finally, the third option is that which provides the second inventor with the greatest protection. In the US, it applies to cases of "non-informing public use."

For the sake of brevity (and somewhat arbitrarily), we shall call the first system "Strict," the second "European," and the third "American." The three patent systems are presented in decreasing order of the protection offered to the first inventor: the Strict system provides the strongest protection, the American the strongest.

3 The model

Outline. There are two firms, an innovator and a follower. Only the innovator can discover the original innovation, but the follower is able to replicate it once the innovator makes the initial discovery.

Innovation occurs according to a Poisson process with hazard rate x, and the innovator's flow R&D expenditure is $c_i(x)$, with $c_i(0) = 0$, $c_i'(x) > 0$ and $c_i''(x) > 0$. The innovator chooses the R&D effort so as to maximize her profit

$$\Pi_i = \int_0^\infty e^{-(x+r)t} \left[xV(T) - c_i(x) \right] dt = \frac{xV(T) - c_i(x)}{x + r}, \qquad (1)$$

[6] In some countries, prior user rights are also assigned to individuals who are merely "preparing for use" at the time of filing or, like in France and Belgium, just have the knowledge sufficient for the use of the invention (WIPO 1988).

where $V(T)$ is the innovator's reward, to be determined presently. Clearly, the optimal innovation effort, $\hat{x}(T)$, increases with $V(T)$.

When the innovation has been successfully developed, the innovator must decide whether to patent or keep it secret. If she patents, she reaps monopoly profit π_m for the duration of the patent, T.[7] The patent is granted in exchange for the disclosure of the innovation: upon expiry of the patent, anybody can use it and the innovator's profits are driven to zero.[8]

Alternatively, the innovator can rely on secrecy.[9] Here the risk is involuntary disclosure (a "leak") or successful duplication by the follower. Leakage of the secret has the same effects as expiration of the patent: the innovation becomes public and profits are driven to zero. We assume that the random event of a leak is distributed exponentially with parameter $z \geq 0$, which will be taken as exogenous throughout the paper. It may be seen as an index of the difficulty of concealing the innovation.

The innovator also loses her monopoly when the follower successfully duplicates the innovation. Duplication requires investment in R&D. The follower starts to invest as soon as the innovator begins to use the innovation, and keeps investing until the new technology is replicated.[10] We assume that successful duplication occurs

[7] It has been argued that patent breadth, not length, is the relevant policy variable, especially with rapid technical progress (see Denicolò, 1996, and the literature cited therein). Although we recognize that patents are generally limited both in scope and length, here we take the length of the patent, T, as a comprehensive index of the strength of patent protection. Explicit analysis of the breadth-length trade-off would complicate matters and add little to the issues that we focus on in this paper.

[8] There is admittedly some tension between the assumption of monopoly in the research and duplication activity, and free entry in the downstream product market. However, our results would carry over with minor changes to the case where the incumbent's profit does not vanish at the patent's expiration: all that matters is that profit falls when the patent expires.

[9] Of course, this is not always the case. Sometimes the commercial use of the innovation entails disclosure, e.g. when the new product can be easily reverse-engineered. This corresponds to a limit case of our model, where the parameter z defined below tends to infinity. The three patent systems are equivalent in this limiting case.

[10] We assume that the achievement of the innovation or its commercial use is observable with no time lag. This assumption is especially appropriate for the case of product innovation, but may also be reasonable with process innovations. Mansfield (1985) finds that information about innovations

according to a Poisson process with hazard rate y. The follower's duplication flow expenditure is represented by $c_f(y)$, with $c_f(0) = 0, c'_f(y) > 0$ and $c''_f(y) > 0$.

Once the follower has duplicated the innovation, he may in turn decide to patent it. In the American system, the follower can then obtain monopoly profit for the duration of the patent. In the European system, he will have to compete with the innovator, and both of them will earn duopoly profits π_d for the duration of the patent, with $0 \leq \pi_d < \pi_m$. If instead the follower does not patent, both the innovator and the follower will gain duopoly profits until the secret leaks out (this also applies to the Strict system).

Summarizing, the timing of the game is as follows: first, the innovator chooses her R&D effort; second, she decides whether or not to patent; third, the follower decides his duplication effort; and finally, the follower decides whether or not to patent (this stage is absent in the Strict system). Our solution concept is subgame perfect equilibrium, so we solve the model proceeding backwards.

The follower's problem. Upon duplication, the follower must decide whether or not to patent. If he does not patent, his expected payoff is

$$W^S = \frac{\pi_d}{z + r}, \tag{2}$$

where r is the interest rate.[11] This is also the follower's payoff in the Strict system.[12]

When the follower patents in the European system, he has to share the market with the first innovator until the patent expires. He will thus decide to patent only

typically is known to rivals within 12 to 18 months of the date of the initial decision by the innovator to develop the new product or process. However, such information may be less easily obtained when the innovator is an outsider to the industry. Whether and when patent applications should be publicly disclosed then becomes a policy issue; see Aoki and Spiegel (2000) for an interesting analysis of the main options.

[11] Throughout the paper, r may incorporate the probability that the innovation is superseded by new technology accruing exponentially with a constant hazard rate.

[12] For simplicity, we assume that the probability of leakage is independent of the number of firms that are practicing the innovation. However, all the results of the paper immediately extend to the case where the probability of leakage is greater under duopoly than under monopoly.

if:

$$\frac{\left(1-e^{-rT}\right)}{r} \geq \frac{1}{z+r}. \tag{3}$$

In the American system, the second-inventor patentee can exclude the first inventor and reap monopoly profits until the patent expires. Therefore, he will patent only if

$$\frac{\left(1-e^{-rT}\right)\pi_m}{r} \geq \frac{\pi_d}{z+r}. \tag{4}$$

Let t^E and t^A be the patent durations that make the follower indifferent between patenting and not in the European and the American system, respectively. Then, in the American system the follower's payoff is

$$W^A = \begin{cases} \dfrac{\pi_d}{(z+r)} & \text{for } T < t^A, \\ \dfrac{\pi_m\left(1-e^{-rT}\right)}{r} & \text{for } T \geq t^A. \end{cases} \tag{5}$$

In the European system, we have instead

$$W^E = \begin{cases} \dfrac{\pi_d}{(z+r)} & \text{for } T < t^E, \\ \dfrac{\pi_d\left(1-e^{-rT}\right)}{r} & \text{for } T \geq t^E. \end{cases} \tag{6}$$

Clearly, $t^A < t^E$: the American system provides the follower with greater incentives to patent.

Let us now consider the follower's optimal duplication effort, $\hat{y}(T)$. Clearly, $\hat{y}(T)$ is increasing in W. Inspection of (2), (5) and (6) confirms that $W^A \geq W^E \geq W^S$ and $dW/dT \geq 0$, where all of these inequalities are strict if the follower patents. Thus, the duplication effort depends positively on the degree of protection accorded to the second inventor, which is highest in the American system and lowest in the Strict system: $\hat{y}^A(T) \geq \hat{y}^E(T) \geq \hat{y}^S$.[13] Furthermore, in all systems the follower's effort is non-decreasing in the patent length, $d\hat{y}(T)/dT \geq 0$, and is increasing if the follower

[13] The first inequality is strict if $T > t^A$, and the second is strict if $T > t^E$.

patents. This is because longer patents provide a higher reward to the follower and make him more aggressive (if he decides to patent).

Figure 1 illustrates the duplication effort in the three systems as a function of the patent length.

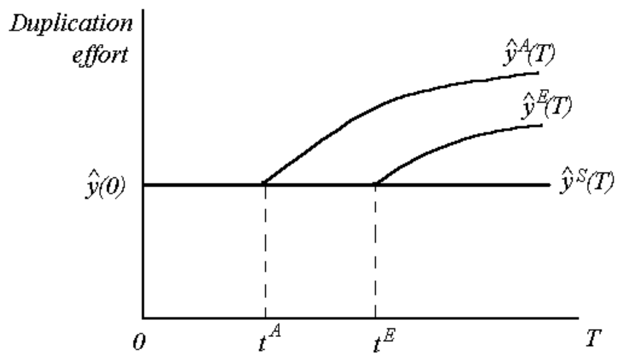

Fig. 1: Duplication effort.

The innovator's problem. In all systems, if the innovator patents she earns $V_P(T) = \pi_m(1 - e^{-rT})/r$. If she does not patent, her payoff depends on the follower's behavior and the patent system.

In the Strict system, and more generally if the follower does not patent, the innovator's payoff is

$$V_{NP}^S = \frac{\pi_m + \hat{y}(0)\dfrac{\pi_d}{z+r}}{\hat{y}(0) + z + r}, \tag{7}$$

since $\hat{y}^S(T) = \hat{y}(0)$ for all T. Since V_{NP}^S is independent of T, while $V_P(T)$ increases with T, there will be a unique cutoff T^S such that the innovator patents if and only if $T \geq T^S$. The cutoff T^S is implicitly determined by the condition $V_P(T) = V_{NP}^S(T)$, i.e.

$$\frac{\left(1 - e^{-rT^S}\right)\pi_m}{r} = \frac{\pi_m + \hat{y}(0)\frac{\pi_d}{z+r}}{\hat{y}(0) + z + r}. \tag{8}$$

In the European system, the innovator's payoff is

$$V_{NP}^{E}(T) = \begin{cases} \dfrac{\pi_m + \hat{y}(0)\dfrac{\pi_d}{z+r}}{\hat{y}(0)+z+r} & \text{for } T \leq t^E, \\ \\ \dfrac{\pi_m + \hat{y}^E(T)\,\pi_d(1-e^{-rT})/r}{\hat{y}^E(T)+z+r} & \text{for } T \geq t^E. \end{cases} \tag{9}$$

Proposition 1 *The European and the Strict systems yield the same equilibrium outcome.*

Proof. First of all, we show that in the European system, the innovator has greater incentives to patent than the follower. Let T^E be the patent duration that makes the innovator indifferent between patenting and not. We must prove that $T^E < t^E$. If the innovator does not patent at $T = t^E$, she gets

$$V_{NP}(t^E) = \frac{\pi_m + \hat{y}\,(0)\,\frac{\pi_d}{z+r}}{\hat{y}\,(0)+z+r}$$

independently of the follower's patenting decision, whereas if she patents she gets

$$V_P(t^E) = \frac{\pi_m(1-e^{t^E})}{r} = \frac{\pi_m}{z+r},$$

where the latter equality follows from the definition of t^E. Since

$$\frac{\pi_m}{z+r} > \frac{\pi_m + \hat{y}\,(0)\,\frac{\pi_d}{z+r}}{\hat{y}\,(0)+z+r},$$

the innovator prefers to patent at $T = t^E$. This means that $T^E < t^E$. Thus, the follower will never patent at equilibrium in the European system, just like in the Strict system. ■

The intuition for this result is straightforward: in the European system, later innovators cannot exclude prior users. They can only shelter themselves from inadvertent leak. This makes the patent more appealing to the first inventor than the follower, as the first can effectively use it to block the latter. This means that if the innovator does not patent, the follower won't either, i.e. second-inventors will never patent in equilibrium. Consequently, the equilibrium outcome in the European system is the same as in the Strict system. In view of Proposition 1, in what follows we shall refer to the European system only, but it should be understood that the same results apply to the Strict system.[14]

Consider next the American system. The innovator's payoff by not patenting is

$$V_{NP}^{A}(T)=\begin{cases}\dfrac{\pi_m+\hat{y}(0)\dfrac{\pi_d}{z+r}}{\hat{y}(0)+z+r} & \text{for } T<t^A,\\[2ex] \dfrac{\pi_m}{\hat{y}^A(T)+z+r} & \text{for } T\geq t^A.\end{cases}\tag{10}$$

Note that $V_{NP}^{A}(T)$ jumps down at $T=t^A$, as the follower's patenting decision deprives the innovator of duopoly profits. Once again, the innovator's payoff if she relies on secrecy is non-increasing in the patent length, T, and therefore there is a cutoff T^A such that the innovator will patent if and only if $T\geq T^A$.

Lemma 1 *In the American system, the follower has greater incentives to patent than the innovator: $T^A\geq t^A$.*

Proof. If $T<t^A$, the follower does not patent (i.e. $\frac{\pi_d}{z+r}>V_P(T)$). Then we have

$$V_{NP}^{A}(T)=\frac{\pi_m+\hat{y}(0)\dfrac{\pi_d}{z+r}}{\hat{y}(0)+z+r}=\frac{\pi_d}{z+r}+\frac{(\pi_m-\pi_d)}{\hat{y}(0)+z+r}>\frac{\pi_d}{z+r}.$$

Combining these two inequalities, we get $V_{NP}^{A}(T)>V_P(T)$ for all $T<t^A$. Thus the innovator will not patent when $T<t^A$, which means that $T^A\geq t^A$. ■

This property of the American system, which stands in contrasts to the opposite result holding in the European system (namely, $T^E<t^E$), is noteworthy and may be

[14] Proposition 1 can be easily extended to the case with N-replicants: the loss due to (further) replication is higher for the innovator than for the first replicant, and, more generally, is higher for the k-th replicant than for the $k+1$-th.

explained as follows. In the American system, the patent can be used both by late and early innovators to exclude all the others. But while the patent rent is the same for all, the first innovator alone can benefit from lead time, and therefore she will be less prone to patenting.[15]

Building on Lemma 1, we can prove the following.

Proposition 2 *(i) In the American system the innovator has lower incentives to innovate, $\hat{x}^A(T) \leq \hat{x}^E(T)$, but greater incentives to patent, $T^A < T^E$, than in the European system. (ii) If the patent life can be freely adjusted, the American system welfare-dominates the European system.*

Proof. (i) We first show that the incentive to patent is greater in the American system than in the European system: $T^A < T^E$. In view of Lemma 1, we must distinguish between two cases, $T^A > t^A$ and $T^A = t^A$. (In Section 4, we elaborate on this distinction). In the first case, T^A will be given by the condition $V_P(T^A) = V_{NP}^A(T^A)$, whereas T^E is determined by $V_P(T^E) = V_{NP}^E(T^E)$. Since $\hat{y}^A(T^A) > \hat{y}(0)$, we have, from (10) and (9), $V_{NP}^A(T^A) < V_{NP}^E(T^A)$. Hence, $T^A < T^E$.

If $T^A = t^A$, it follows from the definition of t^A that $V_P(T^A) = \pi_d/(z+r)$. At $T = T^E$, we have instead

$$V_P(T^E) = \frac{\pi_m + \hat{y}(0)\frac{\pi_d}{z+r}}{\hat{y}(0) + z + r},$$

with

$$\frac{\pi_m + \hat{y}(0)\frac{\pi_d}{z+r}}{\hat{y}(0) + z + r} = \frac{1}{z+r}\frac{(z+r)\pi_m + \hat{y}(0)\pi_d}{\hat{y}(0) + z + r} > \frac{1}{z+r}\pi_d.$$

Hence, $V_P(T^A) < V_P(T^E)$ and $T^A < T^E$ again.

Next we show that in the European system the innovator's reward, and hence her incentive to innovate, are always at least as large as in the American system, and are strictly greater for $t^A \leq T < T^E$. For $T < t^A$, irrespective of the patent

[15] Lemma 1 as well as Proposition 2 also generalize to the case with many replicants.

system, neither the innovator nor the follower patent: $V_{NP}^{A}(T) = V_{NP}^{E}(T) = V_{NP}^{S}$. At $T = t^A$, $V_{NP}^{A}(T)$ jumps down in the American system as the follower elects to patent, whereas $V_{NP}^{E}(T)$ stays constant (nobody patents) up to T^E in the European system . For $t^A \leq T < T^A$, the innovator's reward in the American system is $V_{NP}^{A}(T) = \pi_m/[\hat{y}^A(T)+z+r]$. Since $\hat{y}^A(T)$ is increasing in T, the innovator's reward is decreasing in T. (If $T^A = t^A$, the interval $t^A \leq T < T^A$ is empty.) For $T^A \leq T < T^E$, the innovator patents only in the American system and $V_{NP}^{A} = V_P(T)$, which is increasing in T but is still lower than V_{NP}^{S} for $T < T^E$. Finally, for $T \geq T^E$ the innovator patents and obtains the same reward in both systems.

(ii) Any achievable equilibrium in the European system may be obtained in the American system by suitable choice of the patent life, while the converse is not true. Specifically, any equilibrium obtained in the European system with $T < T^E$ can be replicated in the American system by setting $T < t^A$, while the equilibria obtained in the two systems when $T \geq T^E$ are the same. ■

The intuition underlying part (i) of the Proposition is straightforward. With prior user rights, the innovator is not excluded from the use of the technology upon duplication. She also retains the monopoly for a longer period, as the follower's payoff upon duplication is lower under the European system. Both effects tend to reduce the innovator's propensity to patent in that system. On the other hand, prior user rights strengthen the protection accorded to innovators and thus stimulate innovative effort.

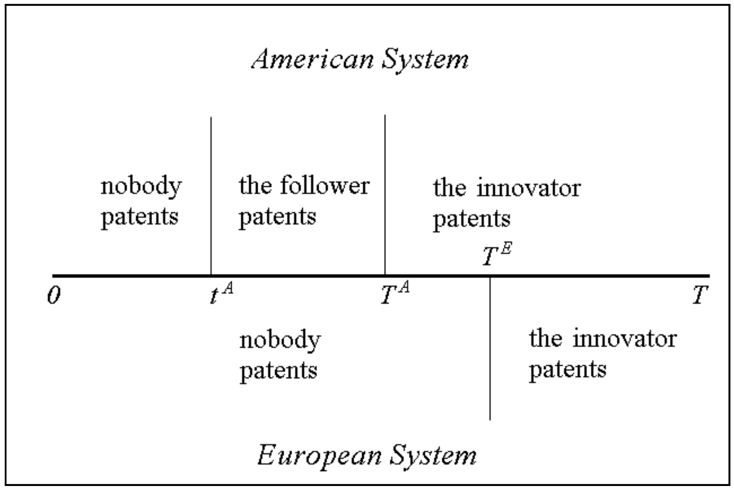

Table 1

Table 1 illustrates the critical values of the patent life in the European and American systems, assuming that $T^A > t^A$. One testable implication of Proposition 2 is that more firms should choose patent protection over secrecy under the American system than under the European system.[16]

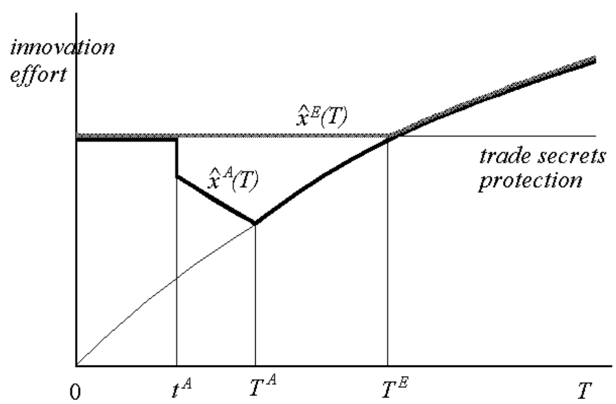

Fig. 2: Innovation effort

Figure 2 illustrates the innovative effort in the two systems. Note the non-monotonicity of R&D effort in the American system. The reason for this non-

[16] American firms are indeed known to patent more than European ones, see OECD (2000). Clearly, there are many other possible explanations to this fact.

monotonicity is that, for intermediate levels of the patent life, the patent represents the prize to the follower rather than the innovator. Longer patent duration fosters greater investment in duplication by the follower and shortens the innovator's lead time.[17]

Proposition 2 establishes a weak dominance result. However, since in the American system the innovator is more prone to patenting, he can be induced to disclose the innovation at lower cost, i.e. with a shorter patent length, than in the European system. Thus, the dominance is strict if the social planner wants the first innovator to patent. If, instead, it is socially desirable to let firms rely on secrecy, it is clearly a matter of indifference whether prior user rights are granted or not.[18] It is then natural to ask whether patent protection should be strong enough to induce the first inventor to patent. This is the subject of the two following Sections.

4 The contract theory of patents

This section addresses the *ex-post* problem of choosing the patent length so as to maximize expected social welfare *assuming that the innovation is already available.* In particular, we ask whether disclosure of the innovation represents a good enough reason to grant temporary monopoly power to the innovator, as is claimed by the contract theory of patents. By focusing on the *ex-post* problem, we disregard the

[17] Non-monotonic R&D effort is also found by Horowitz and Lai (1996), Choi (1998), and Takalo (1998) but for different reasons. In Horowitz and Lai (1996), long patents hurt innovators because they stimulate imitation. In Choi (1998), the length of the patent affects the innovator's incentive to litigate and hence the entry decision of outsiders. In Takalo (1998), like in our paper, longer patents increase the duplication effort. However, the mechanism is different: in Takalo longer patents reduce the duplicator's profit in case he does not succeed, whereas in our model longer patents increase the duplicator's profit if he succeeds.

[18] It will be shown that the patent length should never encourage patenting by the second innovator when the first inventor does not patent. That is, in the American system the optimal patent life never lies between t^A and T^A (see the proof of Proposition 5 in the Appendix). Such a policy would involve wasteful duplication effort and protracted monopoly (secrecy for the innovator, then patent protection for the follower).

impact of the patent policy on the innovator's R&D effort, and thus disentangle the disclosure motive for patents from the traditional reward motive. From this viewpoint, the patent system is seen solely as a means for the diffusion of innovative knowledge.

Ex-post, the social costs of patents and secrets include the deadweight losses associated with monopoly or duopoly, and the duplication effort. Let D_m and D_d denote the monopoly and duopoly deadweight losses, with $D_m \geq D_d \geq 0$. When the patent expires, or a secreted innovation leaks out, the deadweight loss falls to zero.

The expected social loss in the American system can be calculated as follows. If $T < t^A$, neither firm patents. In this case, social loss is comprised of the deadweight loss associated with monopoly until the follower duplicates, the deadweight loss associated with duopoly thereafter, and the duplication costs:

$$\mathcal{L}^A(T) = \frac{D_m + \hat{y}(0) D_d / (z+r) + c_f(\hat{y}(0))}{\hat{y}(0) + z + r}. \tag{11}$$

In the interval $T < t^A$, social loss is independent of the patent length, thus $\mathcal{L}^A(T) = \mathcal{L}(0)$.

If $t^A \leq T < T^A$, the innovator does not patent, but the follower does. Here, the social loss is comprised of the deadweight loss due to the innovator's monopoly before duplication, the deadweight loss of the follower's monopoly created by the patent after duplication, and the duplication costs:

$$\mathcal{L}^A(T) = \frac{D_m + \hat{y}^A(T)(1 - e^{-rT}) D_m / r + c_f\left(\hat{y}^A(T)\right)}{\hat{y}^A(T) + z + r}. \tag{12}$$

In the interval $t^A \leq T < T^A$, $\mathcal{L}^A(T)$ may be either increasing or decreasing in T.

Finally, if $T \geq T^A$, the social loss is solely due to the innovator's patent:

$$\mathcal{L}^A(T) = \frac{D_m\left(1 - e^{-rT}\right)}{r}. \tag{13}$$

In the European system, expected social loss is given by (11) for $T < T^E$, and by (13) for $T \geq T^E$.

Ex-post, the optimal patent life cannot be greater than T^A or T^E since (13) is increasing in T. We look for conditions that guarantee that the optimal patent life in the American (resp., European) system is T^A (resp., T^E), so as to induce the innovator to patent.

To proceed, it is useful to distinguish between two cases: $T^A > t^A$ and $T^A = t^A$. The former case arises when the profits accruing to the innovator thanks to her lead time are large enough to induce her not to patent even if the follower patents, i.e. $V_P(t^A) < V^A_{NP}(t^A)$ (see Figure 3a). When this inequality is reversed, the innovator would not patent if the follower did not patent either, but prefers to patent if the follower does. Thus, the innovator's decision to patent is triggered by the fear of being excluded by the duplicator (see Figure 3b)[19]

Taking into account the definition of t^A, inequality $V_P(t^A) < V^A_{NP}(t^A)$ is equivalent to:

Tough Competition (TC): $\pi_d < \dfrac{(z+r)\,\pi_m}{\hat{y}(0)+z+r}$.

We call this condition "Tough Competition" because it tends to hold when duopoly profits are sufficiently low as compared to monopoly profits.

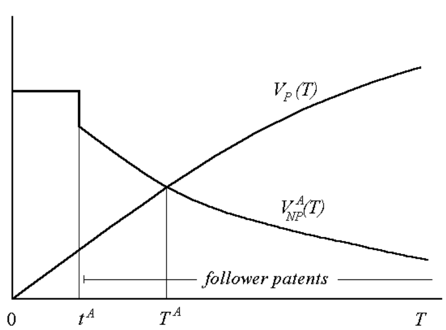

Fig. 3a: Condition TC holds.

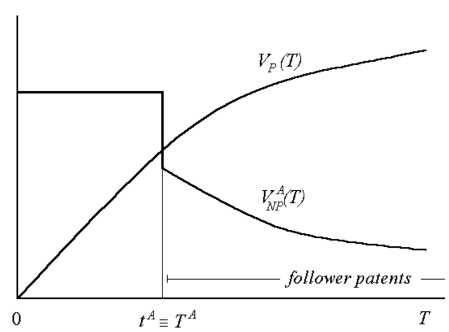

Fig. 3b: Condition TC holds not.

[19] Cohen, Nelson and Walsh (2000) report that pre-emption of rivals' patenting is indeed one major reason why firms do patent. See also the anectodal evidence reported in Merges (1997), where it is argued that firms' patenting decisions often resemble a prisoners' dilemma.

Proposition 3 *Under Tough Competition, the optimal patent length in the American system is* T^A.

Proof. Under TC, T^A will be given by the condition $V_P(T^A) = V^A_{NP}(T^A)$, i.e.

$$\frac{\left(1 - e^{-rT^A}\right)\pi_m}{r} = \frac{\pi_m}{\hat{y}^A(T^A) + z + r}.$$

It follows that at $T = T^A$ we have

$$\mathcal{L}^A\left(T^A\right) = \frac{D_m}{\hat{y}^A\left(T^A\right) + z + r}.$$

Note, from (10) and (11), that $\mathcal{L}^A(T) > D_m/\left[\hat{y}^A(T) + z + r\right]$ for all $T < T^A$. Since $\hat{y}^A(T)$ is non-decreasing in T, we have $\mathcal{L}^A(T) > \mathcal{L}^A\left(T^A\right)$ for all $T < T^A$. ■

Intuitively, under Tough Competition, at $T = T^A$ the expected duration of the innovator's temporary lead if she does not patent equals the patent length. A reduction in the patent length below T^A *de facto* lengthens the duration of monopoly, inclusive of the innovator's temporary lead, since the follower becomes less aggressive and duplication is delayed. (Moreover, for $T^A > T \geq t^A$, monopoly is further prolonged beyond the date of duplication for the duration of the follower's patent.) Since *ex-post* it is desirable to minimize the duration of monopoly, the optimal patent length must induce disclosure by the innovator.

If Condition TC does not hold, we have $T^A = t^A$. In this case, the expected duration of the innovator's temporary lead if she does not patent is shorter than the patent length, and so reducing T below T^A does not lead to longer monopoly. However, if T is reduced below T^A, shorter monopoly will be followed by duopoly rather than by competition. The optimal patent life will then depend on the relative size of the monopoly and duopoly deadweight losses.

Consider the following condition:

Soft Competition (SC): $\dfrac{\pi_d}{\pi_m} \leq \dfrac{D_d}{D_m}$.

To start with, note the analogy between the innovator's and the policy maker's goals: the former maximizes profits, the latter minimizes the deadweight losses associated with those profits (on top of duplication costs). If condition SC holds as an equality, profits and deadweight losses are proportional to each other, and the policy maker tends to prefer what the innovator dislikes. Thus, if the innovator prefers secrecy over patenting, society prefers patenting over secrecy even neglecting duplication costs. When SC holds as an inequality, the deadweight loss associated with duopoly is even greater, and the same conclusion applies.

We can then use the innovator's optimal decision to pin down the optimal patent policy.

Proposition 4 *Under Soft Competition, the optimal patent length in the American (resp., European) system is T^A (resp., T^E).*

Proof. Consider first the European system. By the definition of T^E, given by (7) since $T^E = T^S$, we have:

$$\frac{\left(1-e^{-rT^E}\right)}{r} = \frac{1+\hat{y}\left(0\right)\frac{1}{z+r}\frac{\pi_d}{\pi_m}}{\hat{y}\left(0\right)+z+r},$$

and therefore from (13) we get:

$$\mathcal{L}^A\left(T^E\right) = D_m\frac{1+\hat{y}(0)\frac{1}{z+r}\frac{\pi_d}{\pi_m}}{\hat{y}(0)+z+r}.$$

Thus,

$$\mathcal{L}\left(0\right)-\mathcal{L}^A\left(T^E\right) = \frac{\hat{y}(0)\left(\frac{D_d}{D_m}-\frac{\pi_d}{\pi_m}\right)\frac{D_m}{z+r}+c_f\left(\hat{y}(0)\right)}{\hat{y}(0)+z+r}.$$

If Condition SC holds, the term inside brackets is non-negative, thus $\mathcal{L}\left(0\right) > \mathcal{L}^A\left(T^E\right)$.

With regard to the American system, since $\mathcal{L}^A(T)$ is increasing in T for $T \geq T^A$ and $T^E > T^A$ by Proposition 2, we get *a fortiori* $\mathcal{L}\left(0\right) > \mathcal{L}^A\left(T^A\right)$. ■

Note that Condition SC is sufficient but not necessary, since an additional advantage of patents over secrets is that duplication costs are not borne.

In order to see why inequality $\pi_d/\pi_m \leq D_d/D_m$ is associated with Soft Competition in the downstream product market, consider the case of a drastic cost-reducing innovation. Let $P(Q) = a - bQ$ denote the inverse demand function and normalize to zero the post-innovation marginal cost. The duopoly output may range from monopoly output to competitive output a/b, depending on the intensity of product market competition. We have $\pi_d/D_d = bQ/(a-bQ)$, so the ratio π_d/D_d is increasing in Q. The latter ratio tends to $\frac{1}{2}(\pi_m/D_m)$ when duopoly output tends to monopoly output, and tends to infinity when duopoly output tends to competitive output. Thus $\pi_d/D_d < \pi_m/D_m$ (and Condition SC holds) if competition is soft.[20]

To sum up, in the American system it is optimal to induce the first innovator to patent provided that either Condition TC or SC hold. This means that letting firms rely on secrecy may be the best policy only under limited circumstances, where competition in the product market is neither particularly soft (and SC fails) nor tough (and TC fails), and duplication costs are sufficiently low.[21]

5 Patents, secrets, and innovative effort

We now focus on the innovation stage of the game and consider the impact of the patent length on the innovator's research effort. The policy objective now includes both the *creation* and the *diffusion* of the innovation.

One might think that our results on the optimality of patents in the previous section could only be reinforced by taking into account the effect of the patent policy on the incentives to innovate. With monopoly in R&D, the winner-takes-all effect, which generally tends to lead to overinvestment, disappears, and since innovators

[20] In the linear demand case, Cournot output represents the threshold level for which $\pi_d/D_d = \pi_m/D_m$. The ratio π_d/D_d increases even more rapidly when the demand function is concave, and increases less rapidly (it may even decrease, in which case Condition SC always holds) with convex demand functions.

[21] In the European system, TC does not guarantee that patents outperform secrets: if duplication costs are sufficiently low and SC fails, it may be desirable to let innovators rely on secrecy.

generally fail to appropriate all the social returns from innovations, there will be underinvestment in R&D. Then, it may be desirable to increase the incentives to innovate and this is precisely what strong patent protection is supposed to do.

However, in the American system the incentives to innovate are non-monotonic in the strength of patent protection, as we have seen in Section 3. In particular, innovation effort jumps down at $T = t^A$. This means that in the American system disclosure and innovation are conflicting goals: the fear of being displaced by the duplicator urges the innovator to patent, but hurts her incentives to innovate. Thus, in order for patents to provide the same incentives to innovate as secrets, the patent length has to be raised well above T^A, and Condition TC is no longer sufficient to ensure the superiority of patents.

To proceed, let us normalize to zero the level of social welfare that would be achieved if the innovation were available to all instantaneously and at zero cost. Social loss now includes, in addition to the post-innovation social loss $\mathcal{L}(T)$, the delay in the occurrence of the innovation and the innovator's research expenditure. Thus, ex-ante social loss is defined as

$$\Lambda(T) = \frac{D_0 + x\left(T\right)\, \mathcal{L}(T) + c_i\left(x\left(T\right)\right)}{x\left(T\right) + r}, \tag{14}$$

where D_0 represents the instantaneous social loss borne until the innovation is achieved (this is equal to the social surplus that would be obtained if the innovation were freely available to all).

Proposition 5 *Under Soft Competition, the optimal patent life in the American and the European systems is at least as large as* T^A *and* T^E*, respectively.*

Proof. See the Appendix.

As in the ex-post analysis, if Condition SC holds the optimal patent life encourages the first innovator to patent and disclose the innovation. In contrast to the ex-post welfare analysis, however, Condition SC no longer guarantees that the optimal patent life equals T^A or T^E. A longer patent life may be required to stimulate R&D effort, in which case the optimal patent life has to balance the effects which are familiar from Nordhaus' (1969) analysis: on the positive side, increasing the patent length stimulates R&D investment; on the negative side, it prolongs monopoly deadweight losses. In addition to balancing these effects, however, a new "disclosure" constraint must also be considered when firms can resort to secrecy and Condition SC holds: the patent duration has to be long enough to discourage the innovator from relying on secrecy.

Another difference with the ex-post analysis is that Condition TC no longer ensures that patents are preferable to secrets. If product market competition is tough, trade secret protection may provide a substantial reward to innovators, particularly if duplication costs are high. In these circumstances, duplicative effort is strongly discouraged and trade secrets may represent a powerful appropriation device. If Condition SC fails, the deadweight loss per unit of profit is lower under duopoly than under monopoly, and secrecy may be the most efficient way to reward innovators.

6 Concluding remarks

In this paper, we have analyzed the optimal degree of patent protection (captured by patent length) and the scope of the rights conferred to second inventors when innovators can resort to secrecy to protect their innovations. We have compared three patent systems, which differ in regard to the breadth of the second inventor's patent rights. We have shown that the Strict system, where second inventors cannot patent, is equivalent to the European system where they can patent but cannot exclude the first inventor. In the European system patents are mostly appreciated by innovators, in the American system they are mostly appreciate by duplicators. Provided that the patent length can be suitably chosen, is it optimal to offer broad protection to second inventors (like in the American system).

Our findings shed some light on the proposal to introduce a first inventor defense in the American patent system. Such a policy change is likely to increase the incentive to innovate and reduce the propensity to patent (Proposition 2). While innovative firms are likely to appreciate it, however, it might well have negative welfare effects.

A more complete evaluation of this policy reform, however, should take into account various aspects of the problem that we have left out of our model. First, we have neglected the cost of implementing a patent system, which must include both administrative and litigation costs. As is well known, the latter are substantial, and litigation might be reduced in the presence of prior user rights.

Second, in this paper we have assumed that only one firm is able to obtain the original invention, and another firm is able to duplicate it. We have analyzed a more general setting where both firms race to obtain the original invention, and the loser may subsequently duplicate the innovation obtained by the successful innovator. Clearly, the analysis of the post-innovation game (i.e. the subgame starting when the original innovation has been obtained) is unaffected. The effects of patent policy on the incentives to innovate are now more complicated, however. The reason is that equilibrium investment in R&D now depends not only on the profits to the winner of the patent race, but also on those of the loser. It turns out that if the policy maker wants to give very low incentives to innovate, it must encourage secrecy. Proposition 5 continues to hold only if it is socially optimal to provide sufficiently strong incentives to innovate.

Third, for a given patent length, not necessarily the optimal one, the welfare comparison of the American and European systems is generally ambiguous even from an *ex-post* point of view.[22]

[22] The following can be shown: If product market competition is soft, so that Condition TC fails

Fourth, there is the issue of cumulative innovation. There are two reasons why the cumulative nature of technical progress may reinforce our results on the superiority of patents over secrets. First, disclosure of innovations may entail technological spillovers and spur further progress. Second, the literature on cumulative innovation has stressed the importance of licensing agreements to ensure the appropriate division of the profits from successive innovations among all firms that concurred to the discoveries (see Scotchmer 1999), and secrecy makes it difficult for inventors to license their innovations to others. Formal analysis of these extensions must await further research.

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and SC holds, a move from the American to the European system will never increase, and sometimes decrease, social welfare. In the unlikely case where both TC and SC fail and duplication costs are sufficiently small, when the outcome associated with the American system differs from that associated with the European system, the latter is preferable. Finally, if product market competition is tough, so that condition TC holds and SC fails, the European system is better when the patent life is slightly greater than t^A or slightly lower than T^E, while the American system is preferable for intermediate values of T.

7 Appendix

Proof of Proposition 5. Consider the American system first. Let Condition TC hold. We start by showing that the optimal patent life cannot lie in the interval $\left(t^A, T^A\right)$. Since the R&D effort is lowest at $T = T^A$ and $V_{NP}(T) < \pi_m/r$, any research effort reached in the interval $\left(t^A, T^A\right)$ can also be reached in the $[T^A, \infty)$ region by a suitable choice of the patent length. We can then perform a pairwise comparison between the social loss obtained in the two regions.

Let $\bar{x}$ be any research effort that may be achieved in the interval $\left(t^A, T^A\right)$, say at $T = T_1$, and let $T_2 \geq T^A$ be the patent life that generates the same R&D effort $\bar{x}$. Since the R&D effort at T_1 and T_2 is the same, from (12) and (13) we get

$$\Lambda\left(T_1\right) - \Lambda\left(T_2\right) = \tfrac{\bar{x}}{\bar{x}+r}\left[\mathcal{L}^A(T_1) - \mathcal{L}^A(T_2)\right]$$
$$= \tfrac{\bar{x}}{\bar{x}+r}\left\{D_m\left[\tfrac{1}{\hat{y}(T_1)+z+r} - \tfrac{\left(1-e^{-rT_2}\right)}{r}\right] + \tfrac{\hat{y}(T_1)\,(1-e^{-rT_1})D_m/r + c_f(\hat{y}(T_1))}{\hat{y}(T_1)+z+r}\right\}.$$

At T_1 and T_2 the reward for the innovator has to be the same:

$$\frac{\pi_m}{\hat{y}\left(T_1\right) + z + r} = \frac{\left(1 - e^{-rT_2}\right)\pi_m}{r}.$$

This implies that

$$\Lambda\left(T_1\right) - \Lambda\left(T_2\right) = \frac{\bar{x}}{\bar{x}+r}\frac{\hat{y}\left(T_1\right)\,(1 - e^{-rT_1})D_m/r + c_f\left(\hat{y}\left(T_1\right)\right)}{\hat{y}\left(T_1\right) + z + r} > 0,$$

and thus $\Lambda\left(t_1\right) > \Lambda\left(T_2\right)$.

This means that the patent length should never encourage patenting by the second inventor. (Note that this result holds independently of Condition *SC*.) Such a policy would involve wasteful duplication effort and protracted monopoly (first secrecy for the innovator, then patent protection for the follower).

Let us now compare the social loss in the region $\left[0, t^A\right]$ with that in the region $\left[T^A, \infty\right)$. Consider the patent duration T^E. Here, the innovator is indifferent between patenting and being subject to the potential competition of a non-patenting follower:

$$\frac{\pi_m + \hat{y}\left(0\right)\frac{\pi_d}{z+r}}{\hat{y}\left(0\right) + z + r} = \frac{\left(1 - e^{-rT^E}\right)\pi_m}{r}.$$

Since her reward from research at T^E is equal to her reward from research for $T < T^A$, we have $\hat{x}\left(T^E\right) = x\left(0\right)$.

We have

$$\Lambda\left(0\right) - \Lambda(T^E) \;\; = \frac{x\left(0\right)}{x\left(0\right) + r}\left[\mathcal{L}\left(0\right) - \mathcal{L}^A(T^E)\right],$$

which is positive if Condition SC holds, as shown in the proof of Proposition 4. This result also applies to the European system.

If Condition TC does not hold, we just have to compare $\Lambda\left(t^{L-}\right)$ with $\Lambda(t^{L+})$. We have

$$\Lambda\left(t^{L-}\right) - \Lambda(t^{L+}) \;\; = \frac{x\left(0\right)}{x\left(0\right) + r}\left[\mathcal{L}^A\left(t^{L-}\right) - \mathcal{L}^A(t^{L+})\right],$$

which is positive if Condition SC holds (see Proposition 4). ■

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