Patents, Secrets, and the First-Inventor Defense

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We analyze optimal patent design when innovators can rely on secrecy to protect their innovations. Secrecy has no fixed term but does not preclude accidental disclosure nor independent creation by other inventors. We derive the optimal scope of the rights conferred to such second inventors, showing that if the patent life is set optimally, second inventors should be allowed to patent and to exclude first inventors who have relied on secrecy. We then identify conditions under which it is socially desirable to increase patent life as much as is necessary to induce first inventors to patent. The circumstances in which it is preferable that they rely on secrecy seem rather limited.

1. Introduction

Trade secrets and patents are both legal means of protecting innovative technical knowledge. Although the patent system prohibits certain industries from seeking patent protection and although secrecy is infeasible in others, many inventors can choose between these two avenues of intellectual property protection.[1] Surveys of U.S. firms found that secrets are more ranked highly than patents as a protection mechanism for both

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1. However, innovators cannot benefit from both. If they choose to patent, they must disclose the innovation in the patent specification, which 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 short (one-year) grace period. This prevents inventors from keeping the innovation secret and from applying for a patent only under the threat of impending duplication. See Merges (1997).

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product and process innovations and have increased in importance over the last decade (Levin et al., 1987; Cohen, Nelson, and Walsh, 2000).

One objective of this paper is to ask whether the prevalence of secrecy is desirable socially. To explore this issue, we develop a simple model with an innovation stage and a duplication stage. In the innovation stage, the innovator chooses her research and development (R&D) effort and which type of protection to adopt (patent or secret). In the duplication stage, a follower decides how much to invest to replicate the innovation. The strength of patent protection influences the innovator's patenting decision and research effort, as well as the follower's investment in duplicative activity.

Which forms of protection can a successful duplicator adopt if the first inventor opts for secrecy is also a matter of policy. Notable differences 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. Currently, however, second inventors can patent in most European countries and in the United States.[2] Differences persist regarding whether the first inventor is allowed to continue to practice an innovation patented by others. In Europe, being first inventor is a defense against infringement (in the legal jargon, first inventors are granted prior user rights).[3] In the United States, by contrast, second inventors can exclude anybody else, including first inventors, from the innovation. However, bills introducing a first-inventor defense repeatedly have been put on the floor in the Congress over the last decade.[4] To summarize, we can identify three main policy options: (1) second inventors cannot patent; (2) second inventors can patent, but prior users retain the right to use the innovation; and (3) second inventors can patent and can exclude prior users. Another objective of this paper is to compare these policy options on welfare grounds.

2. The old British rule was changed in 1977 to harmonize the British with the European patent law. In the United States, under 35 U.S.C. § 102(g), a second inventor can claim a valid patent if the innovation was "abandoned, suppressed, or concealed" by the first inventor. The second inventor's patent therefore is valid provided that secret use is interpreted as a form of "concealment." This interpretation has been put forward in *Gore v. Garlock* (721 F.2d 1540, 1983), where 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 exploited commercially. As explained by the court, "Early disclosure is a linchpin of the patent system. As between a prior inventor and a later inventor who promptly files a patent application . . . the law favors the latter." Former decisions distinguished between two cases of public use: "hidden" and "noninforming;" **Q1** only the former would count as a form of concealment. See Harriel (1996) and Merges (1994).

3. In some countries, prior user rights are also assigned to individuals who merely are "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).

4. In November 1999, a first-inventor defense was introduced (*American Inventors Protection Act*) but was limited to "business methods" (35 U.S.C. § 273).

In deciding whether to patent, the innovator weighs the limits of patent protection against the risks associated with secrecy.[5] Unlike patent protection, trade-secret protection precludes neither independent creation by others nor accidental disclosure (a "leak"). Leakage may occur for a variety of reasons: Hackers may violate protected files; new techniques enabling reverse-engineering of the innovation may become available; or the government may expropriate the trade secret (Epstein, 2003). The probability of a leak thus depends both on the technical difficulty of concealing the innovation and the strength of trade-secret protection. By contrast, the risk of duplication depends on the effort exerted by the follower in the duplicative activity.

Patents, in turn, are limited in scope. Because secrecy has no fixed term, however, to have a nontrivial choice problem we must assume that patents are sufficiently "strong." For simplicity, we assume that unexpired patents ensure perfect protection, abstracting from issues of patent invalidity (Anton and Yao, 2003), imitation, or subsequent advances. Thus, we focus on patent length as the relevant policy variable.[6] Given the risks associated with secrecy, then, innovators prefer to patent if and only if the life of the patent is sufficiently long.

The social problem is more complex. Provided that the first inventor patents anyway, a change in patent life involves the standard Nordhaus trade-off. Now, however, the policymaker must decide whether to set a patent life long enough to induce patenting rather than secrecy. A switch from secret to patent protection prevents wasteful duplicative efforts. In addition, market structure under patents generally is different than under secrets, and the deadweight loss associated with patents can be greater or lower than with secrets. Furthermore, if the first inventor patents, longer patents spur innovative activity, but if the first inventor relies on secrecy, prolonging the life of the patent paradoxically may reduce the research effort. Finally, changes in the scope of the patent rights conferred to first and second inventors may have conflicting effects on the innovator's incentives to patent and to invest in R&D.

Our analysis of these effects leads to four main conclusions. First, if first inventors have prior-user rights, it is a matter of indifference whether or not second inventors are allowed to patent (Proposition 1). Second, the introduction of prior-user rights increases the incentives to innovate but reduces first inventors' propensity to patent (Propositions

5. When the innovator has some private information, the decision whether to patent also may be used as a signal: See Horstmann, MacDonald, and Slivinski (1985) and Anton and Yao (2003, 2004) for analyses of such signaling games.

6. As long as patents are "stronger" than secrets, explicit analysis of the patent breadth-length mix would complicate matters and add little to the issues that we focus on in this paper.

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2 and 3). With an arbitrarily fixed patent life, the welfare effect of introducing prior user rights therefore is uncertain. However, our third main conclusion is that in a fully optimized patent system, prior-user rights are not beneficial socially (Proposition 4). More precisely, any outcome obtained in a patent system with prior-user rights can be replicated in a system without prior-user rights by adjusting patent life appropriately. The converse is not true: In the absence of prior-user rights, a shorter patent life suffices to induce innovators to patent (Thus, the welfare dominance may be strict). Finally, we find sufficient conditions ensuring that it is socially desirable that innovators patent (Propositions 5 and 6); the circumstances in which secrecy is preferable socially seem more limited.

Although a lively debate about the introduction of prior-user rights exists in the law literature, to the best of our knowledge there is no formal economic analysis of this issue.[7] The welfare analysis of trade secrets versus patents also is developed poorly. The literature has focused primarily on the optimal patent length–breadth mix when inventors can keep their innovations secret (Gallini, 1992; Takalo, 1998) and on voluntary disclosure of trade secrets.[8] One notable exception is Scotchmer and Green (1990). They 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. Scotchmer and Green (1990) argue that concealment of the intermediate innovation has a negative welfare effect because it increases the rival's research cost. Thus, it can be desirable socially only in limited circumstances (e.g., if it forces the rival to exit the second-stage race and if there is overinvestment in R&D). Except for these special circumstances, any policy that encourages the first innovator to patent the intermediate result (e.g., a move from first to invent to first to file) is welfare improving. Our analysis differs from that of Scotchmer and Green (1990) in that we focus on the effects of secrecy on the product market rather than the

7. The issue of prior-user rights also arises when under a first-to-invent rule two or more individuals claim to have been the first to invent a particular innovation. Prior-user rights would permit those adjudged to be subsequent inventors to continue to exploit the innovation commercially (Harriel, 1996). The work of La Manna, MacLeod, and De Meza (1989) and Maurer and Scotchmer (2002), who ask whether independent rediscoverers should be allowed to use the innovation—but posit that the first inventor always patents—is related to this issue. These papers focus on the implications of the patentee's right to exclude "subsequent" rather than "prior" inventors. **Q2**

8. Battacharya and Ritter (1983) assume that partial disclosure may reduce the cost of capital at the cost of strengthening the firm's rivals in a patent race. Bar (2003) and Baker and Mezzetti (2003) analyze the use of strategic disclosure of intermediate results to prolong a multistage patent race. Ponce (2002) studied the issue of defensive disclosure, i.e., disclosure of unpatentable innovations to prevent rivals from patenting a perfected version. None of these papers performs a welfare analysis.

research industry: In their paper, patents foster competition in second-stage research,[9] whereas in our model they hamper competition in the product market. Nevertheless, our welfare results broadly agree with theirs.

The rest of the paper is organized as follows. In section 2, we outline the model, and in section 3 we characterize the equilibrium under various policy regimes. Section 4 develops the welfare analysis. Section 5 discusses some extensions of the basic model, and section 6 offers some concluding remarks.

2. Model Assumptions

For simplicity, we assume that there are two firms, an innovator, I , and a follower, F. Only I can discover the original innovation, but F can try to replicate it once I makes the initial discovery. In section 5, we discuss how our results extend to a more general set-up.

2.1 The Innovation Stage

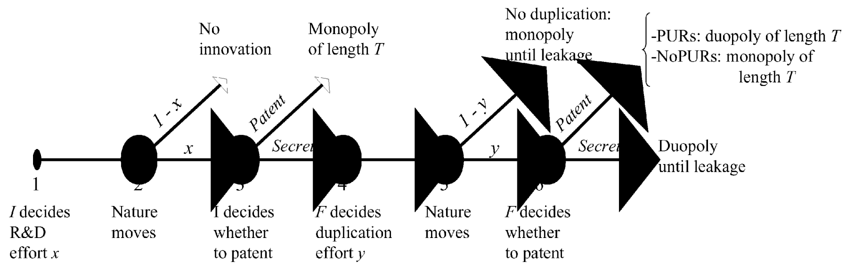
Innovation occurs instantaneously[10] with a probability, x, determined by I's R&D expenditure $c_I(x)$. I chooses the R&D effort so as to maximize her profits $xV_I - c_I(x)$, where V_I is I's reward, to be determined presently. We assume that $c_I'(x) > 0$, $c_I'(0) = 0$, and $c_I''(x) > 0$, so that the optimal innovation effort is positive and increasing with V_I.

If the innovation has been developed successfully, I must decide whether to patent or to keep it secret. By patenting, I reaps monopoly profits π_m for the duration of the patent; T; when the patent expires, I's profits are driven to zero. Alternatively, I can rely on secrecy. Here the risk is accidental disclosure (a "leak") or successful duplication by the follower. We assume that leakage of the secret has the same effects as expiry of the patent; i.e., the innovation becomes public and profits are driven to zero. The random event of a leak occurs according to a Poisson process with arrival rate $z > 0$, which will be taken as exogenous throughout the paper.[11]

9. Scotchmer and Green (1990) focus on the case in which outsiders can conduct second-stage research even if the intermediate technology is patented.

10. Nothing substantial changes if innovation and duplication are assumed to occur in time according to Poisson processes with hazard rates determined by firms' inventive and duplicative efforts, as in the first version of this paper (Denicolò and Franzoni, 2001).

11. If $z = 0$, the follower never patents (unless there is the possibility of further duplication—see section 5) and all the patent systems described in the introduction become equivalent (as in another limiting case, where z tends to infinity and secrecy is no longer a viable option).



Q3

FIGURE 1.

I also loses her monopoly if *F* successfully duplicates the innovation. To take this possibility into account, we next turn to the duplication stage of the model.

2.2 The Duplication Stage

If *I* has concealed the original innovation, *F* can try to duplicate it.[12] To do that, *F* must invest in R&D. Specifically, we assume that duplication occurs with a probability, y, determined by *F*'s duplication expenditure $c_F(y)$. Again, we make the regularity assumptions $c'_F(y) > 0$, $c'_F(0) = 0$, and $c''_F(y) > 0$.

If *F* has duplicated the innovation, he may decide in turn to patent it. In the absence of prior-user rights (PURs), if *F* patents he obtains monopoly profits for the duration of the patent. In the presence of PURs, assuming that *I* can prove to be the first innovator,[13] *F* must compete with *I* in the product market, and both of them will earn duopoly profits, π_d, for the duration of the patent, with $0 < \pi_d < \pi_m$.[14] If instead *F* does not patent, both firms gain duopoly profits until the secret leaks out.

Figure 1 illustrates the timing of actions. All parameter values and actions are common knowledge; thus the game is one of complete information.

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

13. For example, in some European countries the original innovator can deposit a sealed description of the innovation in an official place to create evidence of being first inventor. We relax the verifiability assumption in section 5.

14. The limiting case $\pi_d = 0$ is degenerate in that there is no duplicative effort in the presence of PURs. However, all of our results continue to hold with minor changes.

2.3 Discounting

All future profits are discounted at the common discount rate, r. It is convenient to define

$$\text{discounting-adjusted patent length: } \tau \equiv \int_0^T e^{-rt} dt = \frac{(1 - e^{-rT})}{r}, \tag{1}$$

and

discounting-adjusted duration of the secret:

$$\Phi \equiv \int_0^\infty e^{-zt} e^{-rt} dt = \frac{1}{z + r}. \tag{2}$$

With no discounting, $\tau = T$ and $\Phi = \frac{1}{z}$: the expected duration of the secret. For $r > 0$, future profits are valued less than current profits, and discounting-adjusted durations are shorter: $\tau < T$ and $\Phi < \frac{1}{z}$. Because there is a one-to-one relationship between τ and T, we can focus on τ with no loss of generality. As T goes from 0 to ∞, τ ranges from 0 to $\frac{1}{r}$.

2.4 Welfare

For a variety of reasons, the social returns from the innovation generally differ from the private returns. Let S_m, S_d, and S_c denote the instantaneous social returns from the innovation under monopoly, duopoly, and competition, respectively. Because of the deadweight losses associated with market power, we assume that $S_m \leq S_d \leq S_c$.

Social welfare is defined as the expected value of the discounted social returns from the innovation, less innovation, and duplication costs. If the innovator patents, assuming that the social discount rate equals r, social welfare is[15]

$$W = x \left[\tau S_m + \left(\frac{1}{r} - \tau \right) S_c \right] - c_I(x), \tag{3}$$

i.e., with probability x the innovation is achieved and society obtains a flow of S_m for the duration of the patent plus a flow of S_c thereafter (with probability $1 - x$ the innovation is not achieved and so there are no social benefits from innovative activity), less the innovation cost.

15. $\frac{1}{r} - \tau = \int_T^\infty e^{-rt}\, dt$ is the discounted value of a unit flow earned from time T onward.

If neither I nor F patent, we have[16]

$$W = x\left\{(1-y)\left[\Phi S_m + \left(\frac{1}{r} - \Phi\right) S_c\right] + y\left[\Phi S_d + \left(\frac{1}{r} - \Phi\right) S_c\right] - c_F(y)\right\} - c_I(x). \quad (4)$$

If I succeeds, with probability $(1 - y)$ the innovation is not duplicated, and society obtains a flow of S_m for the expected duration of the secret plus a flow of S_c thereafter. With probability y, the innovation is duplicated, and so duopoly rather than monopoly will prevail until the secret leaks out. In both cases, society now also bears the duplication cost $c_F(y)$.

Finally, if only F patents—we show here that this only can occur in the absence of PURs—social welfare is

$$W = x\left\{(1-y)\left[\Phi S_m + \left(\frac{1}{r} - \Phi\right) S_c\right] + y\left[\tau S_m + \left(\frac{1}{r} - \tau\right) S_c\right] - c_F(y)\right\} - c_I(x), \quad (5)$$

which differs from (4) in that successful duplication now entails monopoly for the duration of the patent and competition thereafter.

3. Equilibrium

As usual, we solve the model proceeding backward. Initially we assume that second inventors are allowed to patent, focusing on the effects of PURs. Later we deal with the case where second inventors are not allowed to patent.

3.1 The Follower's Problem

Let us suppose that I has made and secretly has used the original innovation and that F has succeeded in duplicating it. Then, F must decide whether or not to patent. Clearly, he will patent if and only if the life of the patent is sufficiently long. More precisely, F's expected payoff if she does not patent is $V_{F,NP} = \frac{\pi_d}{z+r} = \Phi\pi_d$.[17] If F patents, her payoff depends on the scope of her rights. Without PURs, second-inventor patentees can exclude the first inventor and so by patenting F reaps monopoly

16. $\frac{1}{r} - \Phi = \int_0^\infty (1 - e^{-zt})e^{-rt}\,dt$ is the expected discounted value of a unit flow earned from the timing of leakage onward.

17. For simplicity, we assume that the probability of leakage is independent of the number of firms 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.

profits until the patent expires: $V_{F,P}(\tau) = \frac{(1-e^{-rT})\pi_m}{r} = \tau\pi_m$. Thus, F will patent if and only if $\tau \geq \frac{\pi_d}{\pi_m}\Phi \equiv \tau_F$. (To fix ideas, we assume that a firm patents when it is indifferent between patenting and not.) With PURs, F must share the market with I until the patent expires, earning $V_{F,P}^{PUR}(\tau) = \frac{(1-e^{-rT})\pi_d}{r} = \tau\pi_d$. (The superscript *PUR* denotes a system with prior-user rights.) Thus, F will patent if and only if $\tau \geq \Phi \equiv \tau_F^{PUR}$. It is evident that PURs reduce F's incentives to patent (i.e., $\tau_F^{PUR} > \tau_F$). Let $V_F = \max[V_{F,P}(\tau), V_{F,NP}]$ be F's reward; clearly, F's reward is greater in the absence of PURs and in both systems increases with τ (strictly so if F patents).

Moving one stage back, let us now consider F's optimal choice of duplication effort. F chooses y so as to maximize $yV_F - c_F(y)$. Under our regularity conditions, the optimal effort, $\hat{y}(\tau)$, is (weakly) increasing in F's reward and so $\hat{y}(\tau) \geq \hat{y}^{PUR}(\tau) > 0$.[18] Furthermore, in both systems F's effort is nondecreasing in the patent length and is increasing if F patents.

3.2 The Innovator's Problem

Assuming that the innovation has been obtained, I must decide whether or not to patent. By patenting, I earns $V_{I,P}(\tau) = \tau\pi_m$. If I does not patent, her payoff depends on F's patenting decision. If F does not patent, I's payoff is

$$V_{I,NP} = (1 - \hat{y}_0)\Phi\pi_m + \hat{y}_0\Phi\pi_d,$$

where $\hat{y}(0) \equiv \hat{y}_0$. That is, I earns monopoly profits for the expected duration of the secret if F does not duplicate and if duopoly profits for the same expected period if F duplicates. With PURs, if F patents we have

$$V_{I,NP}^{PUR}(\tau) = [1 - \hat{y}^{PUR}(\tau)]\Phi\pi_m + \hat{y}^{PUR}(\tau)\tau\pi_d.$$

Since I cannot be excluded, she earns duopoly profits for the duration of F's patent. Without PURs, if F patents we have $V_{I,NP}(\tau) = [1 - \hat{y}(\tau)]\Phi\pi_m$, because now I can be excluded by F.

Clearly, I will choose to patent if the patent life is sufficiently long. Let τ_I^{PUR} be the cutoff patent duration that makes I indifferent between patenting and not with PURs, and let τ_I be this cutoff in the absence of PURs. In both cases, such a cutoff value exists and is unique.[19] Lower

18. Inequality $\hat{y}^{PUR}(\tau) > 0$ follows from $\pi_d > 0$ and $c_F'(0) = 0$.

19. In both cases, $V_{I,NP}(0) > V_{I,P}(0) = 0$ and $V_{I,P}(\frac{1}{r}) > V_{I,NP}(\frac{1}{r})$. This means that in both cases a cutoff value exists. To show uniqueness, it suffices to note that $V_{I,P}(\tau)$ increases with τ, whereas (1) $V_{I,NP}(\tau)$ is nonincreasing in τ (because $\hat{y}(\tau)$ is nondecreasing in τ),

cutoffs mean that shorter patents suffice to induce I to patent and are associated with a greater propensity to patent.

Finally, in the first stage of the game I chooses the R&D effort so as to maximize her profits $xV_I - c_I(x)$, where $V_I = \max[V_{I,P}(\tau), V_{I,NP}(\tau)]$. Our regularity conditions on $c_I(x)$ imply that the optimal R&D effort, $\hat{x}(\tau)$, is a (weakly) increasing function of I's payoff.

3.3 A Policy-Equivalence Result

Before proceeding, we pause here to show that the equilibrium that obtains with PURs also would arise if second inventors were not allowed to patent. The reason is that with PURs F never patents in equilibrium.

Proposition 1: *The equilibrium outcome arising with PURs is equivalent to the outcome that would obtain if second inventors were not allowed to patent.*

Proof. It suffices to show that with PURs I has greater incentives to patent than F: $\tau_I^{PUR} < \tau_F^{PUR}$. If I does not patent at $\tau = \tau_F^{PUR}$, she gets $(1 - \hat{y}_0)\Phi\pi_m + \hat{y}_0\Phi\pi_d$, whether or not F patents, whereas if I patents she gets $\Phi\pi_m$. Since $\pi_m > \pi_d$, I strictly prefers to patent at $\tau = \tau_F^{PUR}$. This means that $\tau_I^{PUR} < \tau_F^{PUR}$; consequently, with PURs F never patents in equilibrium, as if F could not patent. □

Proposition 1 means that from a policy perspective there is no loss of generality in assuming that second inventors can patent and in focusing on the effects of PURs. The reason why I has greater incentives to patent than F and thus preempts him is that with PURs F patents only if the life of the patent is at least as long as the expected duration of the secret—since F cannot exclude I, he earns duopoly profits anyway. However, when $\tau = \phi$, I would be indifferent between patenting and not only if there were no risk of duplication; with a positive probability of duplication, I strictly prefers to patent.

3.4 The Incentives to Patent and to Innovate

We already know that PURs affect duplicative effort negatively. Next we show that with PURs, I' propensity to patent is lower, but the incentive to innovate is greater than in the absence of PURs.

Proposition 2: *The innovator's propensity to patent is lower in the presence of PURs: $\tau_I \leq \tau_I^{PUR}$.*

Proof. We start noting that in the absence of PURs, F has greater incentives to patent than I: $\tau_I \geq \tau_F$. To prove this claim, observe that

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and (2) $V_{I,NP}^{PUR}(\tau)$ is continuous and weakly increasing in τ but increases less steeply than $V_{I,P}(\tau)$.

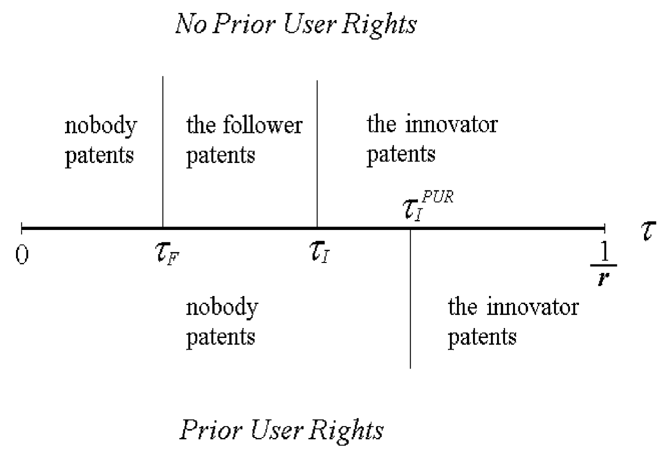

FIGURE 2.

if $\tau < \tau_F$, F does not patent (i.e., $\tau\pi_m < \Phi\pi_d$) and so

$$V_{I,NP} = \Phi[(1-\hat{y}_0)\pi_m + \hat{y}_0\pi_d] \geq \Phi\pi_d > \tau\pi_m = V_{I,P}(\tau).$$

Thus, I will not patent when $\tau < \tau_F$, which means that $\tau_I \geq \tau_F$.

To proceed, we must distinguish between two cases, $\tau_I > \tau_F$ and $\tau_I = \tau_F$. The first case arises when $V_{I,NP}(\tau_F) > V_{I,P}(\tau_F)$, so that I relies on secrecy even in the anticipation that a successful F patents. In contrast, in the second case $V_{I,NP}(\tau_F) \leq V_{I,P}(\tau_F)$ and I engages in preemptive, or "defensive," patenting for fear of being excluded by F.

In the first case, τ_I is given by the condition $V_{I,P}(\tau_I) = V_{I,NP}(\tau_I)$, i.e. $\tau_I = [1 - \hat{y}(\tau_I)]\Phi$, whereas

$$\tau_I^{PUR} = (1-\hat{y}_0)\Phi + \hat{y}_0\Phi\frac{\pi_d}{\pi_m}.$$

Since $\hat{y}(\tau_I) > \hat{y}_0$, we have $[1-\hat{y}(\tau_I)]\Phi < (1-\hat{y}_0)\Phi + \hat{y}_0\Phi\frac{\pi_d}{\pi_m}$, and hence $\tau_I < \tau_I^{PUR}$.

In the second case, where $\tau_I = \tau_F = \Phi$, one has $V_{I,P}(\tau_I) = \Phi\pi_d$, which means that $\tau_I = \Phi\frac{\pi_d}{\pi_m} \leq \Phi[(1-\hat{y}_0) + \hat{y}_0\frac{\pi_d}{\pi_m}] = \tau_I^{PUR}$. □

With PURs, I is not excluded from the use of the new technology upon duplication and also is more likely to retain a monopoly, as F's duplication effort is lower. Both effects tend to reduce I's propensity to patent.

Figure 2 illustrates the cutoff values of the patent life in the two patent systems.

Proposition 3: *For any patent length, the innovator's incentives to innovate with PURs are at least as high as without PURs.*

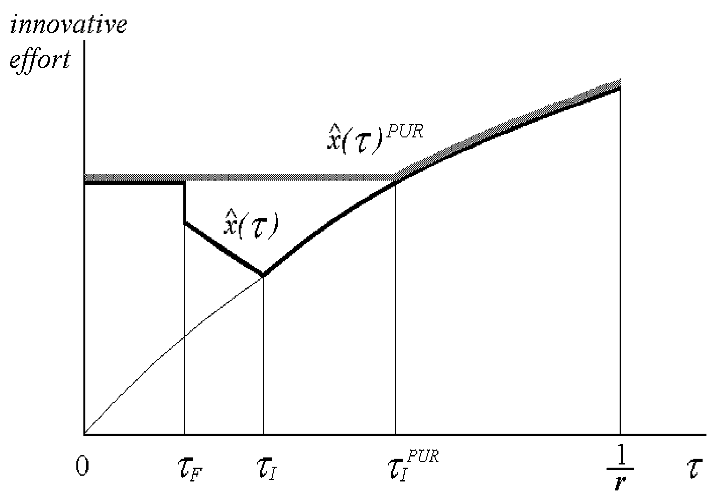

FIGURE 3.

Proof. For $\tau < \tau_F$, irrespective of the patent system, neither firm patents and so I's payoff is independent of the patent system. At $\tau = \tau_F$, $V_{I,NP}(\tau)$ jumps down as F elects to patent, whereas $V_{I,NP}^{PUR}(\tau)$ stays constant (nobody patents) up to τ_I^{PUR}. For $\tau_F \leq \tau < \tau_I$, I's reward in the absence of PURs is $V_{I,NP}(\tau) = [1 - \hat{y}(\tau)]\Phi\pi_m$. Since $\hat{y}(\tau)$ is increasing in τ, I's reward is decreasing in τ. (If $\tau_I = \tau_F$, the interval $\tau_F \leq \tau < \tau_I$ is empty.) For $\tau_I \leq \tau < \tau_I^{PUR}$, I patents only without PURs and so $V_{I,NP} = V_{I,P}(\tau)$, which is increasing in τ but still is lower than I's payoff with PURs (by definition, $V_{I,NP}^{PUR}(\tau_I^{PUR}) = V_{I,P}(\tau_I^{PUR})$). Finally, for $\tau \geq \tau_I^{PUR}$ I patents and obtains the same reward in both systems. □

Figure 3 illustrates the innovative effort with and without PURs. It is worth noting that without PURs patent protection may be sufficiently strong to induce I to patent and yet may lead to less innovative effort than secrecy. Note also that in the absence of PURs, R&D effort is not monotone in the strength of patent protection. The reason for this non-monotonicity is twofold: First, V_I jumps down at $\tau = \tau_F$ because when F patents, I is deprived of duopoly profits; second, for intermediate levels of the patent life (i.e., for $\tau_F \leq \tau < \tau_I$), the patent represents the prize to F, not I. In this interval, longer patent durations spur duplicative activity and lower the probability that I retains monopoly power.[20]

20. Nonmonotonic R&D effort also is 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

4. Welfare Analysis

We now turn to the welfare analysis. This section has two main objectives. The first, more specialized objective is to analyze the optimal scope of the rights to be assigned to second inventors. The second broader objective is to ask whether society should encourage patenting and disclosure instead of secrecy. We address each of the issues in turn.

4.1 Prior-User Rights

Imagine a policymaker who controls the patent length and must decide whether to grant PURs. Proposition 4 shows that granting PURs cannot raise, and in some circumstances can reduce, social welfare.

Proposition 4: *Suppose first inventors are assigned PURs and take any patent length τ. Then, there exists a (possibly different) patent length τ', which in the absence of PURs yields at least the same welfare level.*

Proof. We actually prove a stronger result, namely that any equilibrium outcome (patenting choices, innovative and duplicative efforts) that arises in the presence of PURs with patent life τ can be replicated in the absence of PURs with a suitable patent life τ'.

To prove this claim, it is useful to refer to Figure 2. Consider any patent life τ in the interval $[0, \tau_I^{PUR})$. With PURs, all of these patent lives support the same equilibrium outcome, in which neither *I* nor *F* patent, $\hat{y}(\tau) = \hat{y}_0$, and $\hat{x}(\tau) = \hat{x}(0)(\equiv \hat{x}_0)$. Such an equilibrium outcome can be reproduced in the absence of PURs by setting $\tau' = 0$ (in fact, any τ' in the interval $[0, \tau_F)$ would do). Next consider any patent life τ in the interval $[\tau_I^{PUR}, \frac{1}{r})$, and set $\tau' = \tau$. Observe that since $\tau_I^{PUR} \geq \tau_I$ (Proposition 2), *I* makes precisely the same patenting choice (i.e., she patents), earns the same monopoly rents, and exerts the same innovative effort with and without PURs. Consequently, social welfare is the same with and without PURs. □

Proposition 4 establishes a (weak) dominance result. It means that if patent length is chosen optimally, introducing PURs cannot raise social welfare. However, it is of some practical importance to consider the welfare effects of introducing PURs assuming some fixed, and perhaps arbitrary, patent life. Propositions 2 and 3 tell us that such a move has two conflicting effects. The positive effect of introducing PURs is that

(1998), as in the present paper, longer patents increase the duplication effort. However, the mechanism is different: In Takalo (1998) 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.

the innovator's incentive to innovate increases (With monopoly in R&D, any increase in R&D effort is welfare enhancing). The negative effect is that the incentive to patent is lower, and so there will be more duplicative activity, which is socially wasteful. A more highly structured model is required to compare the two effects.

More generally, though, Proposition 4 means that for an optimizing policymaker a patent system with PURs is weakly dominated. In particular, it appears from Figure 2 that in the absence of PURs a shorter patent life suffices to induce I to patent and disclose the innovation: For $\tau \in [\tau_I, \tau_I^{PUR})$, I patents only in the absence of PURs. If the optimal patent life lies in this interval, introducing PURs definitely lowers social welfare.[21]

4.2 Patents versus Secrets

Our next goal is to ascertainwhether it is preferable socially to have first inventors patent or rely on secrecy. In view of Proposition 4, we focus on a patent system without PURs (but our results hold also with PURs). The policymaker can influence I's decision whether to patent by changing the patent life. Thus, the problem is whether the patent life should be greater or lower than τ_I.

Three effects can play a role in this decision. First, patents protect first inventors from independent rediscovery, and so setting $\tau \geq \tau_I$ prevents wasteful duplicative activity. Second, market structure under patents is generally different than under secrets. In our model, when I chooses patent protection, monopoly prevails until the patents expires and until the market becomes perfectly competitive. If instead I chooses trade-secret protection, there can be monopoly or duopoly (eventually displaced by perfect competition when the secret leaks out). Consequently, the deadweight loss under patenting generally is different than under secrecy. Third, if the patent life is sufficiently long, I's reward is greater than under secrecy. In the standard Nordhaus trade-off, greater R&D effort comes at the cost of greater deadweight loss, but when the balance needs to be struck in favor of innovations, the option to increase I's reward becomes valuable socially.

Abstracting from the last effect, we shall proceed by comparing policy options that lead to the same innovative effort.[22] This allow us to make some progress without making more specific assumptions on

21. In the absence of PURs it also is possible to support equilibria in which only F patents, but we show that such equilibria are welfare dominated.

22. This approach initially was suggested by Gilbert and Shapiro (1990) and has been applied routinely in the literature on the optimal patent breadth–length mix.

R&D costs. As a preliminary result, we show that it never is optimal to set patent length so that I does not patent and F does.

Lemma 1: *It never is optimal to set patent life so as to encourage patenting by second inventors only.*

Proof. We must show that the optimal patent life never lies in the interval $\tau_F \leq \tau < \tau_I$. This is trivially true if $\tau_F = \tau_I$. Thus, suppose that the interval $\tau_F \leq \tau < \tau_I$ is not empty—the case illustrated in Figures 2 and 3.

Let us take any patent life τ_1 with $\tau_F \leq \tau_1 < \tau_I$ and choose $\tau_2 \geq \tau_I$ so as to generate the same incentive to innovate as τ_1, i.e., such that $\hat{x}(\tau_2) = \hat{x}(\tau_1)(= \bar{x}$, say). To show that such a patent life τ_2 exists, note that $\hat{x}(\tau)$ reaches its minimum at τ_I, it is continuous for $\tau \geq \tau_I$, and $\hat{x}(\frac{1}{r}) > \hat{x}(0)$ (see Figure 3).

Then, from (3) and (4) we get

$$W(\tau_2) - W(\tau_1) = \bar{x}\,\{-\tau_2 + [1 - \hat{y}(\tau_1)]\Phi + \hat{y}(\tau_1)\tau_1\}\,(S_c - S_m) + \bar{x}c_F(\hat{y}(\tau_1)).$$

By construction, I's reward is the same at τ_1 and τ_2: $\tau_2\pi_m = [1 - \hat{y}(\tau_1)]\Phi\pi_m$. This implies that

$$W(\tau_2) - W(\tau_1) = \bar{x}\,\{\hat{y}(\tau_1)\tau_1(S_c - S_m) + c_F(\hat{y}(\tau_1))\} > 0.$$

This shows that any patent length τ_1 in the interval $\tau_F \leq \tau_1 < \tau_I$ is dominated by another feasible policy and therefore cannot be optimal. □

The economic intuition underlying this result is that patenting by second inventors involves wasteful duplication effort and a longer expected duration of monopoly, which results both from secret use by I and from F's patent right.

Next, we focus on the different market structure under patents and secrets. Patents grant the innovator monopoly power, whereas trade secrets provide innovators with a combination of monopoly and duopoly profits. To determine which form of protection is better, a crucial issue is whether duopoly entails more deadweight loss *per unit of innovator's profits* than monopoly. Let us assume:

Soft Competition: *The ratio of duopoly deadweight loss to per-firm profits is at least as large as the ratio of monopoly deadweight loss to monopoly profits:*

$$\frac{\mathrm{S_c - S_d}}{\pi_\mathrm{d}} \leq \frac{\mathrm{S_c - S_m}}{\pi_\mathrm{m}}. \tag{6}$$

To illustrate, consider a homogeneous good industry, with linear demand function $P(Q) = a - Q$ and constant marginal costs. Suppose that there is a drastic cost-reducing innovation, and normalize to zero the post-innovation marginal cost. Denoting by Q_d aggregate duopoly output, we let Q_d range from monopoly output $Q_m = \frac{1}{2}a$ to competitive output $Q_c = a$ as competition increases, without making any specific assumption on the nature of product market competition. In this linear demand case, condition (6) holds as an equality when firms compete à la Cournot and as a strict inequality if duopoly output is lower than under Cournot competition (e.g., because firms can to some extent collude); it is violated if duopoly output is greater than under Cournot competition.[23] In general, the ratio $(S_c - S_d)/\pi_d$ tends to $2(S_c - S_m)/\pi_m$ when Q_d tends to monopoly output (as $S_d \to S_m$ and $\pi_d \to \frac{1}{2}\pi_m$ for $Q_d \to Q_m$), implying that condition (6) tends to be met when product market competition is not too intense, whence the name soft competition.[24]

Proposition 5: *Under soft competition, patent life always should be long enough to induce the first inventor to patent.*

Proof. Take any patent life τ_1 with $0 \leq \tau_1 < \tau_F$, say $\tau_1 = 0$, and compare the ensuing equilibrium to that arising with $\tau = \tau_I^{PUR}$. Because both policies lead to the same R&D effort ($\hat{x}_0$), from (4) and (3) we get

$$W(\tau_I^{PUR}) - W(0) = \hat{x}_0\{[-\tau_I^{PUR} + (1 - \hat{y}_0)\Phi](S_c - S_m) + \hat{y}_0\Phi(S_c - S_d) + c_F(\hat{y}_0)\},$$

where we have used the fact that $\hat{x}(\tau_I^{PUR}) = \hat{x}_0$. Next, recall that: $\tau_I^{PUR} = (1 - \hat{y}_0)\Phi + \hat{y}_0\Phi\frac{\pi_d}{\pi_m}$. This implies that

$$W(\tau_I^{PUR}) - W(0) = \hat{x}_0\left\{\hat{y}_0\Phi[(S_c - S_d) - \frac{\pi_d}{\pi_m}(S_c - S_m)] + c_F(\hat{y}_0)\right\}. \qquad (7)$$

Under soft competition the term inside square brackets is nonnegative and therefore $W(\tau_I^{PUR}) > W(0)$. This means that the optimal patent life is at least as long as τ_F. By Lemma 1, it cannot lie in the interval $\tau_F \leq \tau < \tau_I$ and so it must be at least as long as τ_I, such that I patents. □

23. In the linear demand case we have $(S_c - S_m)/\pi_m = 1/2$ and $(S_c - S_d)/\pi_d = (a - Q_d)/Q_d$. Clearly, the ratio $(S_c - S_d)/\pi_d$ is decreasing in Q_d, i.e., in the intensity of product market competition. It tends to *1* when Q_d tends to monopoly output and to 0 when Q_d tends to competitive output a. With Cournot competition, $Q_d = \frac{2}{3}a$, and thus $(S_c - S_d)/\pi_d = 1/2 = (S_c - S_m)/\pi_m$.

24. When the demand function is concave, as Q_d increases the ratio $(S_c - S_d)/\pi_d$ decreases more rapidly—starting from $2(S_c - S_m)/\pi_m$—than in the linear case, while it decreases less rapidly (it even may increase, in which case inequality (6) always holds) with convex demand functions.

The intuition is as follows. The condition soft competition ensures that the deadweight loss per unit of I's profits is lower under monopoly than under duopoly. Thus, it is less costly from the social point of view to reward innovators through monopoly rents than a combination of monopoly and duopoly rents. When one compares patent policies that lead to the same R&D effort (i.e., to the same expected reward for the innovator), soft competition then implies that the expected deadweight loss is lower with patents than with secrets.

As is clear from (7), an additional advantage of patents is that society does not bear the duplication cost, $c_F(y)$. This means that patents may be better than secrets even when soft competition fails. To illustrate, consider again the linear demand example illustrated above, and suppose that $c_F(y) = \frac{1}{2}\beta y^2$. Provided that β is sufficiently large relative to V_F to yield interior solutions, the optimal duplicative effort is $\hat{y} = \frac{V_F}{\beta}$. In this linear-quadratic example, it always is desirable to induce innovators to patent.

Proposition 6: *In the linear-demand, quadratic-duplication-cost example with interior solutions, patent life always should be long enough to induce the first inventor to patent.*

Proof. Substituting $\hat{y} = \dfrac{V_F}{\beta}$ into (7) we get

$$W(\tau_I^{PUR}) - W(0) = \hat{x}^S \frac{\Phi^2 \pi_d}{\beta}\left[(S_c - S_d) - \frac{\pi_d}{\pi_m}(S_c - S_m) + \frac{1}{2}\pi_d\right].$$

With a linear-demand function and zero marginal costs we have $\pi_d = \frac{1}{2} Q_d(a - Q_d)$, $S_c - S_m = \frac{1}{8}a^2$, and $S_c - S_d = \frac{1}{2}(a - Q_d)^2$. Then, the term inside square brackets reduces to $\frac{1}{2}(a - Q_d)^2 \geq 0$, and thus $W(\tau_I^{PUR}) > W(0)$. The conclusion then follows as in the proof of Proposition 5. □

Although this result rests on specific functional forms, it nicely illustrates one theme of this paper, namely that secrets are costly socially in that they invite duplicative activity. Note that investment in duplicative activity is greater when product market competition is softer. This observation and Proposition 5 suggest that trade-secret protection is particularly costly, from the social point of view, when competition is weak.

Are there circumstances under which secrecy nonetheless is preferable? Our discussion so far suggests that three conditions must be met: (1) product market competition must be fierce; (2) duplication costs must be small; and (3) there must be little gain from (or scope for) increasing I's reward beyond the level guaranteed by secrecy. These conditions can be met simultaneously.[25] However, when product market competition is fierce and when duplication costs are small, I's reward under secrecy tends to be small, and so it is likely that society may gain substantially from increasing R&D investment. This suggests that the circumstances under which secrecy is preferable socially are rather limited.

5. Extensions

In this section we briefly report on three extensions of the basic model: many potential innovators and duplicators, imperfect enforcement of PURs, and the existence of administrative and legal costs.

5.1 Competition in R&D and Repeated Duplication

Our basic model assumes that only I can innovate and that only F can duplicate the concealed innovation. However, it is immediate to allow for the possibility of competition in research. Indeed, all that matters for our results is that there exists a continuous, nondecreasing relationship between equilibrium aggregate innovative effort and the innovator's reward. Such a relationship would be exhibited by many conceivable models of R&D competition.[26]

Concerning duplication, the main effect of allowing for many potential duplicators is that the second inventor becomes more keen on patenting. In the absence of PURs, we have $\tau_F \leq \tau_I$, and so the fact that τ_F falls does not alter the qualitative properties of the equilibrium. However, in the presence of PURs, in the basic model we have $\tau_F^{PUR} > \tau_I^{PUR}$ (Proposition 1), and so multiple duplication may have deeper consequences. Proposition 1, however, continues to hold under weak additional conditions. To illustrate, suppose there are two potential duplicators, $F1$ and $F2$, and extend the basic game by assuming

25. As an example, suppose that innovation costs $c_I(x)$ are so small that $\hat{x}(\tau) = 1$ for all values of τ, and consider again a quadratic-duplication-cost function. $c_F(y) = \frac{1}{2}\beta y^2$. However, let us now assume that β is very small, such that $\hat{y}(\tau) = 1$ for all values of τ. In this special case, $\tau_I = \tau_F = \tau_I^{PUR}$ and W is piecewise constant in τ, with a jump at $\tau = \tau_I^{PUR}$. From (7), one calculates $W(\tau_I^{PUR}) - W(0) = \{\Phi[(S_c - S_d) - \frac{\pi_d}{\pi_m}(S_c - S_m)] + \frac{1}{2}\beta\}$. If soft competition fails, the term inside square brackets is negative. If, in addition, the marginal duplication costs β is sufficiently low, we have $W(0) > W(\tau_I^{PUR})$; i.e., social welfare jumps down at $\tau = \tau_I^{PUR}$, and so secrets turn out to be better than patents.

26. However, continuity may be an issue in some circumstances. For example, if two firms race for the innovation and if the loser becomes the follower in the subsequent duplication stage, equilibrium investment in R&D depends not only on I's profits but also on F's. A small change in the patent life that induces I to switch from secrets to patents then can lead to a large change in the R&D equilibrium effort. Such discontinuities would prevent the application of the technique of proof used in Lemma 1 and Propositions 5–6.

that if $F1$ succeeds and in turn conceals the innovation, $F2$ can invest to reobtain the innovation. If $F2$ also succeeds, he in turn can choose to patent or keep the innovation secret. Assuming for simplicity $z = 0$, in the presence of PURs $F2$ would never patent. However, $F1$ patents provided that

$$\tau\pi_d \geq (1 - y_2)\Phi\pi_d + y_2\Phi\pi_t,$$

where y_2 is $F2$'s effort and where π_t is the individual profits with three active firms. Thus, $\tau_F^{PUR} = (1 - y_2)\Phi + y_2\Phi\frac{\pi_t}{\pi_d}$. Proposition 1 continues to hold under the weak condition $\frac{\pi_m}{\pi_d} \geq \frac{\pi_d}{\pi_t}$, which is met in many oligopoly models.[27] To show this, note that if I does not patent at $\tau = \tau_F$, she gets

$$(1 - y_1)(1 - y_2)\Phi\pi_m + [y_1(1 - y_2) + y_2(1 - y_1)]\Phi\pi_d + y_1y_2\Phi\pi_t < \tau_F^{PUR}\pi_m,$$

where $\tau_F^{PUR}\pi_m = (1 - y_2)\Phi\pi_m + y_2\Phi\frac{\pi_t}{\pi_d}\pi_m$, and the inequality follows by condition $\frac{\pi_m}{\pi_d} \geq \frac{\pi_d}{\pi_t}$. Therefore, I strictly prefers to patent at $\tau = \tau_F^{PUR}$, and so $\tau_I^{PUR} < \tau_F^{PUR}$. The intuition is that the loss due to (further) duplication is greater for I than for $F1$ (and, more generally, is greater for the kth duplicator than for the $k + 1$th).[28]

5.2 Enforcing Prior-User Rights

The basic model posits that I can prove to be the first inventor so that PURs can be enforced if duplication occurs. Suppose instead that I is adjudged to be the first inventor only with probability μ. If F patents, he now gets $\tau[\mu\pi_d + (1 - \mu)\pi_m]$, and so

$$\tau_F^{PUR}(\mu) = \frac{\Phi\pi_d}{\mu\pi_d + (1 - \mu)\pi_m}.$$

The basic model corresponds to $\mu = 1$. All of our results continue to hold provided that $\mu \geq \bar{\mu}$, where $\bar{\mu}$ is defined implicitly as the solution to

$$\frac{\pi_d}{\bar{\mu}\pi_d + (1 - \bar{\mu})\pi_m} = \frac{\hat{y}_0\pi_d + (1 - \hat{y}_0)\pi_m}{\pi_m}.$$

27. For example, with linear demand and constant marginal costs, in the Cournot equilibrium $\frac{\pi_t}{\pi_d} = \frac{9}{16}$ and $\frac{\pi_d}{\pi_m} = \frac{4}{9}$. With conjectural variations, inequality $\frac{\pi_m}{\pi_d} \geq \frac{\pi_d}{\pi_t}$ holds for any value of the conjectural variations parameter. Soft competition also must be restated by assuming that the ratio of deadweight loss to per-firm profits increases with the number of active firms.

28. This discussion shows that the assumption $z > 0$ also may be viewed as a shortcut for allowing for multiple duplications.

If $\mu < \bar{\mu}$, we have $\tau_F^{PUR}(\mu) < \tau_I^{PUR}(\mu)$, and so Proposition 1 no longer holds. However, it is still true that in a fully optimized patent system second inventors should be allowed to patent and PURs should not be granted.[29] Our results concerning the welfare comparison of patents and secrets also continue to apply.

5.3 Administrative Costs

Our analysis could be extended to take into account the costs of enforcing patents and secrets. The high administrative and legal costs of the patent system are well documented in the empirical literature. However, secrecy also is costly because of the direct costs of enforcing trade secret laws and because holders of concealed inventions may use inefficient marketing or production strategies to protect the secret. There is little evidence on the relative costs of patents and secrets. For instance, in an empirical investigation on civil litigation case files, Lerner (1994) finds that patent and trade-secret issues are commonplace and occur with about the same frequency. However, he also finds that small firms tend to rely on secrecy more often than big firms; one possible explanation is that secrecy is less costly that patenting. Then, let us normalize to zero the costs of secrecy and suppose that the innovator must pay a lump-sum cost, $\Psi \geq 0$, to obtain the patent and a flow cost, $\psi \geq 0$, to renew and to enforce it (that is, we interpret Ψ and ψ as the difference in costs between patents and secrets), so that the discounted total cost of the patent is $\Psi + \tau\psi$. One can show easily that all the results in section 3 continue to hold with this more general formulation.[30] Obviously, however, if Ψ and ψ are large, the welfare comparison between patents and secrets becomes more uncertain.

6. Concluding Remarks

In this paper, we have compared patent systems that differ in regard to the breadth of second inventors' patent rights. We also have asked

29. To show that this policy dominates a system in which second inventors cannot patent, the same argument as in the proof of Proposition 4 applies. Concerning a patent system with PURs, it is easy to see that for all values of μ we have $\tau_F^{PUR}(\mu) \geq \tau_F$ and $\tau_I^{PUR}(\mu) \geq \tau_I$, with equality holding for $\mu = 0$, in which case PURs are ineffective. One also can show, proceeding as in the proof of Lemma 1, that with PURs the optimal patent life never lies in the interval $\tau_F^{PUR}(\mu) \leq \tau < \tau_I^{PUR}(\mu)$. These facts imply that for any τ there exists a τ' such that $W(\tau') = W^{PUR}(\tau)$, i.e., a welfare-dominance result.

30. This is not true if either Ψ or ψ are negative, i.e., if secrets are more costly to enforce than patents.

whether patent policy should induce innovators to choose patent or secret protection.

Our analysis offers several insights that may be useful in the evaluation of proposed policy changes. First, in the presence of prior-user rights, first inventors have more incentives to patent than second inventors, who therefore never patent in equilibrium. Consequently, introducing prior-user rights in a system without them—e.g., in the United States—has the same effect as preventing second inventors from patenting. Second, in a fully optimized system, prior-user rights never are welfare enhancing. Thus, if the current patent term of 20 years is optimal socially, a move to a system with prior-user rights could not raise, and could reduce, social welfare. However, economic theory suggests that the optimal patent life varies from industry to industry (and, perhaps, from innovation to innovation). If the policymaker is restricted to choose the same patent life in all industries, we are in a second-best world. Here, introducing prior-user rights would increase the incentives to innovate at the cost of greater duplicative efforts with an uncertain overall welfare effect. Prior-user rights then may be optimal in those industries in which there is significant underinvestment in R&D and competition is sufficiently intense.

We also have shown that trade-secret protection is preferable socially only in limited circumstances. This contrasts with the prevalence of secrecy documented in the empirical literature, suggesting that a policy that more actively promotes the dissemination of innovative technological knowledge may be desirable. Although we have focused on patent length, granting broader patents is an alternative way to make patents more attractive. Again, however, if the policymaker is restricted to choose the same patent life in all industries, it well may happen that certain industries—for instance, those in which the risk of leakage is lowest—prefer to rely on secrecy. In such a framework, the social cost of decreasing patent protection is not necessarily that innovation is discouraged, as in the standard Nordhaus trade-off, but rather that more innovations will be kept secret. The analysis of optimal patent policy in this framework requires a more highly structured model and is left for future work.

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