Strategic Secrecy of Pending Patents*

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Abstract

In many jurisdictions, the existence and contents of patent applications are unknown to third parties until the application is published by the patent office at least 18 months after the initial filing. The patent applicant can expedite this public awareness of the existing application and the respective technology by announcing the patent application before its automatic publication. In our model, the applicant balances a negative effect of disclosure on its informational advantage in the short run (*value of secrecy*) with a positive long-run effect stemming from potential deterrence of a rival's R&D (*value of deterring innovation*). We give conditions under which announcing the pending patent deters a rival's innovation. We show that, in equilibrium, the applicant's decision to announce and the rival's decision to innovate are non-monotonic in the strength of the application and the strength of the patent.

Key words: information disclosure, innovation, patenting, pending patents, perfect Bayesian equilibrium, R&D.

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1 Introduction

In the United States and many other jurisdictions, pending patent applications are typically published 18 months after the initial filing. This practice has been criticized (Modigliani, 1999) because it puts inventors' intellectual property into the public realm before a final grant decision about the patent has been made,[1] affording competitors' more time to engineer around the invention (Bessen and Meurer, 2006) or depriving the inventors of using other means of intellectual property protection (e.g., trade secrets). Recent empirical evidence, however, indicates that inventors generate little value from the secrecy of their patent applications (Graham and Hegde, 2012), and attach more strategic importance to the duration of pendency *after* the publication of the application (Henkel and Jell, 2010). Unless the inventors mark their products ("pending patent" or "patent applied for"), the existence of a patent application *before* its publication is private information. Disclosing the fact that a technology or invention exists and a patent has been applied for (without disclosing technical details), does not necessarily generate the same effects as the publication of the application including the technical details. This is because, without the details, competitors will not be able to engineer around, nor do inventors forego the opportunity to seek patent protection elsewhere. Announcing the existence of a pending patent, however, can affect rivals and competition in other ways. In this paper, we study when and why patent applicants announce that they have applied for a patent and thus forego the secrecy during the initial 18 months of its pendency—before the automatic publication by the patent office.

We propose a model that captures a simple trade-off. On the one hand, an announcement of a pending patent application informs a firm's rival of potential intellectual property, and this awareness can deter the rival's own innovation. Also, such an announcement can generate uncertainty. Gunderman and Hammond (2007) conclude: "So your competitor's fear of the unknown may provide you a temporary but substantial advantage in the marketplace. Use it well!" A similar argument can be found in Koenen and Peitz (2011). On the other hand, a patent application does not only hold information about the technology for which patent protection is sought. The fact that a patent has been applied can convey information about the a firm's business and technology management and the composition of its patent portfolio. Disclosing some of this information can have immediate (or short-run consequences).

In our model a technology leader (*she*) and a technology follower (*he*) produce differentiated products and compete in prices. The leader may have access to a cost-reducing technology for which she has a pending patent application. Both the existence and the details of the technology and the patent application are private information. The follower initially produces under the status-quo technology and during stage 1 has the option to innovate. If he decides to innovate, then he gains access to a cost-reducing technology for competition at stage 2. We assume that this decision is publicly observable. Between stage 1 and stage 2, the leader's patent application is published and examined by the patent office. Before the follower makes his innovation decision and the firms compete at stage 1, the applicant leader can announce the existence of a pending patent (without disclosing it technical details), allowing the follower to update his belief about the leader's cost structure at stage 1. Because of the automatic publication of the patent application, competition at stage 2 is always under symmetric information. The follower, however, is aware of the leader's cost-structure at stage 1 only if the applicant leader has disclosed its type.

[1] For the United States, Popp et al. (2004) estimate the average pendency of a potential application to be 27 months (for 1976 through 1996), and Hall and Harhoff (2012) find that the average patent in 2002 is pending for 24 months. Both estimates put a considerable amount of time between the publication of pending patent applications and their final examination.

We assume that both the patent application and, if granted upon examination, the patent are probabilistic. This means the patent is granted with less than certainty. Moreover, provided that it is granted, the patent is then valid with less than certainty. This probability of patent validity can also be interpreted as the probability that the follower's new technology (arriving at stage 2) is infringing on the leader's patent.[2] We refer to the patent's allowance rate (the probability that it granted) as *application strength* and to the probability that the patent is found valid (or that the follower infringes) as *patent strength*. Both application strength and patent strength are common knowledge.

Our model captures a simple inter-temporal trade-off. First, the applicant leader's announcement informs the follower of (probabilistic) property rights that may deter follow-up innovation. With such an announcement, the follower knows with certainty that a patent application and ensuing patent exists. He further knows that in case of the patent being granted, he will infringe upon this patent with a given probability. If this threat of infringement is sufficiently strong, then it will deter the follower from innovating. This gives the leader a competitive advantage at stage 2, generating licensing revenues that are higher than when the follower innovates. Because the follower's innovation materializes with a delay, this *value of deterring innovation* is a long-run effect.

Second, by announcing the pending patent the leader reveals the existence of the cost-reducing technology and notifies the follower that it produces at lower cost. Given our assumption of price competition (i.e., prices are strategic complements (Bulow et al., 1985)), the follower anticipates lower prices by the leader and will respond with lower prices himself. Announcing the pending patent therefore renders the follower a more aggressive competitor at stage 1. Not announcing the pending patent and keeping the follower in the dark (with softer competition at stage 1) generates a *value of secrecy* in the short run.

The leader's value of deterring innovation ultimately depends on the strength of the leader's intellectual property (i.e., the probability that the follower must pay license fees) and the market life expectancy of the technology (capped by the maximum length of patent protection). In other words, a product or technology generation (to which the cost-reducing technology applies) with a short shelf life yields smaller expected license revenues than one with a longer life cycle. The leader's value of secrecy, on the other hand, is independent of the probability of license fees and the market life expectancy of the technology. The latter is because after the publication of the application there is no more uncertainty in the product market at stage 2.

Juxtaposing the long-run effects of announcing the pending patent (value of deterring innovation) with the short-run costs (value of secrecy), the leader is more likely to announce when the probability of license revenues as well as the duration of license revenues is higher. The same effects, however, make innovation more profitable for the follower. This is because the leader's benefits of deterring innovation are equal to the follower's benefits from innovating.

The equilibrium of the message-innovation game before stage-1 competition yields a non-monotonic relationship between the strength of the leader's intellectual property and her announcement as well as the follower's innovation. The conventional view is that stronger (known) intellectual property rights are more likely to deter innovation. In our model, we assume that the rival is not aware of potential intellectual property unless the applicant leader announces a pending patent. We find that (with patent strength low enough), the applicant is more likely to announce the pending patent (and deter innovation) for intermediate values than low values of

[2] The former interpretation presumes that if the patent is valid, the follow-up technology is infringing with probability one. Under the latter interpretation, the patent is always valid but infringement is probabilistic.

application strength. For high values, however, such an announcement is not effective because the follower innovates irrespective of the applicant's choice. Analogously (for application strength high enough), the applicant finds it profitable to deter innovation only for intermediate values of application strength. For low values, deterrence is not effective, whereas for high values deterring innovation has little value because the license revenues in case of innovation are relatively high as the follower is infringing on the patent with sufficiently high probability.

Fo the model, we make a number of critical assumptions. First, we model competition as a price setting game where prices are strategic complements. Second, the leader's technology and the patent application are given and not modeled as a decision variable.

Third, cost-reducing technologies are substitutes. This implies that if the follower innovates and the resulting technology does not infringe on the leader's patent, then the leader will not generate any license revenues. With complementary technologies this is likely to be different, yielding a possible incentive for the leader to encourage the follower's investment and thus increase expected license revenues.

Fourth, in line with the rules in the United States and numerous other jurisdictions, all pending patent applications are automatically published (typically) 18 months after the patent has been filed. We assume that the applications are published and examined between the market interaction at stage 1 and stage 2. This implies that there is no pendency of the patent application after its publication. Such pendency (arising from delays at the patent office) is studied in Popp et al. (2004) or Regibeau and Rockett (2010). Harhoff and Wagner (2009) and Henkel and Jell (2010) show that firms attach a strategic value to the pendency period and, if possible, seek to prolong it.

Fifth, the leader's announcement is ex post verifiable. Any deceptive announcement or "false marking" has legal consequences,[3] and we assume these are binding in the sense that a leader without a patent application will not deceptively announce.

The structure of the paper is as follows. In Section 2, we introduce the model. In Section 3, we present the equilibrium results for the price competition at both stages. In Section 4, we derive the equilibrium for the message-innovation game before stage-1 competition and discuss its comparative statics. In Section 5 we conclude. The formal proofs are relegated to the Appendix.

2 Model

2.1 Market Environment

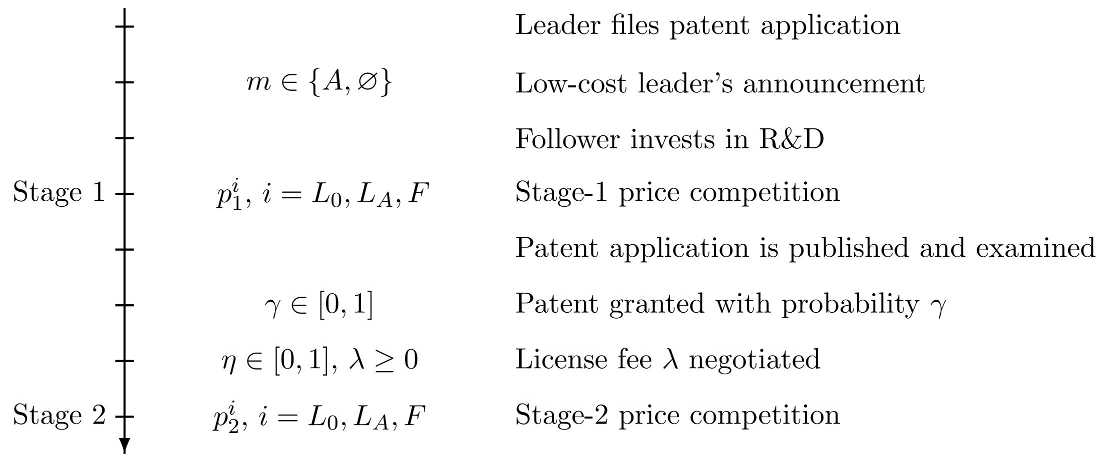
We consider an industry in which two price competitors—a technology *leader* L (she) and a technology *follower* F (he)—produce goods that are close but imperfect substitutes in stages $t = 1, 2$. We assume a simple linear demand function with substitution parameter $\delta \in [0, 1]$ and denote firm i's demand in $t = 1, 2$ as function of both firms' prices by

$$D^i(p_t^i, p_t^j) = 1 - p_t^i + \delta p_t^j \tag{1}$$

[3] By Title 35, Article 292, of the U.S. Code ("False marking"), the use of the term "patent pending" or "patent applied for" is permitted so long as a patent application has actually been filed. If these terms are used when no patent application has been filed, it is deemed as a deceptive act and a fine of up to $500 may be imposed for every such offense. Under Forest Group, Inc. v. Bon Tool Co., 590 F.3d 1295 (Fed. Cir. 2009), the current interpretation of "offense" has each mis-marked article constitute an offense, which permits theoretical damages in the hundreds of millions of dollars for high-volume consumer goods.

for $i, j = L, F$, $i \neq j$. The substitution parameter δ captures the degree of competition, where a higher δ reflects fiercer competition; $\delta = 1$ denotes the case of perfect substitutes and $\delta = 0$ the case of two separate markets so that firms are monopolists.

Figure 1: Sequence of Events and Notation



At the outset of the game, the leader may have access to a new technology that allows her to produce at low marginal cost. We normalize these costs to zero, $c_L = 0$. The follower does not have access to this technology and produces at marginal cost $c_F = c$. This c captures the *significance of innovation*, which higher values of c representing greater cost reductions from a new technology relative to the status quo. For the status-quo costs, we assume an upper bound that guarantees that firm i's demand is always non-negative in equilibrium.

Assumption 1. *Marginal costs under the status-quo technology are* $c \in \left(0, \frac{1}{1-\delta}\right]$.

The basic structure of competition in this product market environment is depicted in Figure 1. Before competition in stage 1, the follower can invest in R&D at cost $K > 0$ to reduce his production costs. If the follower decides to undertake the R&D project, its success is certain. The realization of this R&D investment, however, is delayed and the cost-reducing technology is available for competition only in stage 2. For simplicity we assume that both firms observe the outcome of the follower's R&D.

We assume for the baseline model that before the follower innovates, the low-cost leader has filed a patent application for its cost-reducing technology. The low-cost leader is therefore a *patent applicant*. The *strength* of the patent application determines the probability $\gamma \in [0, 1]$ that the patent is granted. The application is examined after stage-1 but before stage-2 market competition. Given the application is granted, we assume probabilistic patents (Lemley and Shapiro, 2005) where the strength of the patent determines the probability $\eta \in [0, 1]$ that the follower's newly developed technology is infringing on the leader's patent. In a case of infringement, the follower must obtain a license from the leader at cost λ to use the cost-reducing technology and produce at zero marginal cost. If he does not obtain a license, the follower's marginal production cost is c.

2.2 Information

In the baseline model, only the low-cost leader type with the cost-reducing technology can apply for a patent. This decision to patent a technology is beyond the scope of our analysis, and we assume that a low-cost type always applies for the patent. The existence and the technical details of this new technology are private information, and the follower's prior belief that the leader is of the low-cost type and therefore patent applicant, $L = L_A$, is $\theta = \Pr(L = L_A)$ with $\theta \in (0, 1)$. Conversely, with probability $1 - \theta = \Pr(L = L_0)$ the follower believes the leader is of the high-cost type L_0 without access to the new technology and marginal costs of c.

Before the follower makes his investment decision, the applicant can reveal her type by announcing that she holds a pending patent. We assume the applicant does not reveal the technical details of her technology but discloses only the *existence* of a cost-reducing technology. The applicant L_A's message space is $M_A = \{A, \varnothing\}$. She can choose to announce a pending patent and reveal her type as low-cost leader and applicant, $m = A$, or remain silent, $m = \varnothing$. We denote by $(\mu, 1 - \mu)$ the applicant's (mixed) strategy profile where $\mu = \Pr(m = A|L = L_A)$ is the probability that she announces her pending patent, and $1-\mu = \Pr(m = \varnothing|L = L_A)$ is the probability that she remains silent on the matter. The high-cost leader L_0 (non-applicant) cannot announce a pending patent so that $M_0 = \{\varnothing\}$.

We assume that the patent application is still pending after the stage-1 market profits are realized, upon which it is automatically published.[4] The leader's type is then revealed and stage-2 competition is under symmetric information. Moreover, because the technical details of the technology are published with the patent application, the follower can use the technology and produce at marginal cost $c_F = 0$ irrespective of its own innovation decision (i.e., license free when the leader's patent application is denied). We assume that the (now published) patent application is examined and the patent granted or denied before stage-2 competition. In terms of our model this means that there is no product-market interaction of the two firms between publication and examination of the patent application.

Competition at stage-1 (before the patent application is published by the patent office) is under asymmetric information. The follower can update his prior belief θ upon observing the leader's announcement. Because a high-cost leader (without a patent application) cannot announce a pending patent, once the follower has observed $m = A$, his posterior belief that the leader is of low-cost type L_A is $\hat{\theta}(A) = 1$. If, instead, the leader does not announce the pending patent, $m = \varnothing$, then the follower forms his posterior belief $\hat{\theta}(\varnothing) = \Pr(L = L_A|m = \varnothing)$ according to Bayes' rule:

$$\hat{\theta}(\varnothing) = \frac{\Pr(m = \varnothing|L = L_A)\Pr(L = L_A)}{\Pr(m = \varnothing|L = L_A)\Pr(L = L_A) + \Pr(m = \varnothing|L = L_0)\Pr(L = L_0)}$$

where $\Pr(L = L_A) = \theta$ is the follower's prior belief that the leader is the low-cost type and patent applicant, and $\Pr(L = L_0) = 1 - \Pr(L = L_A)$. Moreover, $\Pr(m = \varnothing|L = L_A) = 1 - \mu$ and $\Pr(m = \varnothing|L = L_0) = 1$ are the probabilities that the applicant and the non-applicant do not

[4] The American Inventors Protection Act of 1999 requires that utility patent applications be published after eighteen months regardless of grant status unless the applicants assert that they are not not pursuing patent protection outside of the United States. See Johnson and Popp (2003), Popp et al. (2004), Aoki and Spiegel (2009), Koenen and Peitz (2011), or Graham and Hegde (2012).

announce the application. Upon observing $m = \varnothing$, the follower's posterior belief in $t = 1$ is then

$$\hat{\theta}(\varnothing) = \frac{\theta\,(1-\mu)}{1-\theta\mu}. \tag{2}$$

We can see that for any $\mu \in [0,1]$ it must hold that $\hat{\theta}(A) > \hat{\theta}(\varnothing)$ with $\hat{\theta}(\varnothing) \in [0,\theta]$.[5]

2.3 Payoffs

The firms earn market profits at two stages. At stage 1, the marginal production costs for the follower are c. Moreover, the follower's posterior belief about the leader's marginal costs is

$$c^e = \big(1 - \hat{\theta}(m)\big)c. \tag{3}$$

We denote the follower's Bayesian Nash equilibrium profits from price competition at stage 1 by $\pi_1^F(c, c^e|\hat{\theta}(m))$, given the follower's belief $\hat{\theta}(m)$ following the leader's decision m. The applicant's Bayesian Nash equilibrium profits are $\pi_1^L(0, c|\hat{\theta}(m))$, and the non-aplicant's Bayesian Nash equilibrium profits are $\pi_1^L(c, c|\hat{\theta}(m))$. Furthermore, because at stage 2 the leader's type is public information, stage-2 competition is under symmetric information. Firm i's Nash equilibrium profits are denoted by $\pi_2^i(c_i, c_j)$. For the firms' expected payoffs at their decision stage, we assume different (symmetric) weights for stages $t = 1, 2$ with 1 the weight for $t = 1$ and $\alpha > 0$ the weight for $t = 2$. This parameter α captures the market life expectancy of the cost-reducing technology or the shelf life of the respective product generation for which the technology is used.

The applicant can announce her pending patent before the follower makes his innovation decision. This decision by the follower is denoted by r with $r = 1$ if the follower innovates and $r = 0$ if otherwise. Given message m, the follower's expected gross profits, as functions of m and r and gross of innovation costs K, are

$$\begin{aligned}\Pi_F(m,r) = \pi_1^F(c, c^e|\hat{\theta}(m)) + \alpha \Big\{ &\hat{\theta}(m) \left[\pi_2^F(0,0) - \gamma\lambda + r\,(1-\eta)\,\gamma\lambda\right] + \\ &\big(1-\hat{\theta}(m)\big) \left[\pi_2^F(c,c) + r\left[\pi_2^F(0,c) - \pi_2^F(c,c)\right]\right] \Big\}.\end{aligned} \tag{4}$$

The follower anticipates access to a cost-reducing technology either by way of the applicant (in exchange for license fees) or because of his own innovation. For the case in which the leader is not an applicant (with posterior belief $1 - \hat{\theta}(m)$), the follower has marginal costs of zero if he has innovated, whereas the leader has marginal costs c.[6] For the case in which the leader is a patent applicant (with follower's posterior belief $\hat{\theta}(m)$), the follower pays license fees λ with probability γ if he has not innovated and with probability $\eta\gamma$ if he has innovated (so that his new technology infringes on the leader's patent with probability η).

[5]For instance, in a *separating equilibrium*, in which the applicant reveals her type with certainty (i.e., $\mu = 1$), the posterior belief is $\hat{\theta}(\varnothing) = 0$ and $\hat{\theta}(A) = 1$. In a *pooling equilibrium*, in which the applicant never reveals her type (i.e., $\mu = 0$) the posterior belief is $\hat{\theta}(\varnothing) = \theta$ and $\hat{\theta}(A) = 1$. Finally, in a *hybrid equilibrium* (or mixed-strategy equilibrium), in which the applicant reveals her type with a probability $\mu \in (0,1)$, the posterior belief is $\hat{\theta}(\varnothing) \in (0,\theta)$, as in equation (2), and $\hat{\theta}(A) = 1$.

[6]For the payoffs in this case we implicitly assume that the leader knows of the follower's innovation and there is no knowledge transfer from the follower (with successful innovation) and the leader (without cost-reducing technology) at this point, because of a lack of IP protection and Arrow's disclosure paradox (Arrow, 1962).

The applicant chooses her optimal message m taking into account the effect this decision has on her Bayesian Nash equilibrium profits at stage 1 and on the follower's innovation decision $r(m)$ and thus on the leader's Nash equilibrium profits at stage 2. The applicant's expected payoffs are

$$\Pi_A(m) = \pi_1^L(0, c|\hat{\theta}(m)) + \alpha\left[\pi_2^L(0,0) + \gamma\lambda - r(m)\,(1-\eta)\,\gamma\lambda\right]. \tag{5}$$

The applicant's *value of deterring innovation*, $\Pi_A(m|r=0) - \Pi_A(m|r=1)$, stems from her licensing revenues and is equal to $\alpha\,(1-\eta)\,\gamma\lambda^*$. The non-applicant does not anticipate any license revenues and expects payoffs of

$$\Pi_0(m) = \pi_1^L(c, c|\hat{\theta}(m)) + \alpha\left[\pi_2^L(c,c) - r(m)\left[\pi_2^L(c,c) - \pi_2^L(c,0)\right]\right]. \tag{6}$$

Because the non-applicant's stage-2 profits are lower when the follower has access to a cost-reducing technology so that $\pi_2^L(c,c) > \pi_2^L(c,0)$, both leader types prefer a follower who does not innovate. However, only the patent applicant has the means to influence the follower's decision through announcing her pending patent.

2.4 Equilibrium Concept

The equilibrium concept for this message-innovation game before stage-1 competition is perfect Bayesian equilibrium (PBE) where the applicant L_A's strategy $(\mu^*, 1-\mu^*)$ is optimal given the follower's posterior belief $\hat{\theta}(\varnothing)$ and $\hat{\theta}(A)$ and the follower's investment decision, and the follower's posterior belief is consistent with the leader's equilibrium strategy. The non-applicant remains silent with a probability of one.

3 Price Competition and Equilibrium Profits

In this section, we first derive the equilibrium profits for price competition at stages 1 and 2. At stage 1, price competition is under asymmetric information, and the Bayesian Nash equilibrium profits depend on the follower's belief $\hat{\theta}(m)$. The follower's expectations of the leader's marginal costs are $c^e = \big(1-\hat{\theta}(m)\big)c$. At stage 2, the patent application has been published and the leader's type is public information. Price competition is under symmetric information. Recall that the follower's marginal costs in $t=1$ are $c_F = c$. In $t=2$, his costs are $c_F = 0$ if he innovates or obtains a license from the leader, and $c_F = c$ otherwise. We summarize the equilibrium profits for stage 1 (price competition with asymmetric information) and stage 2 (price competition with symmetric information) in the following lemma.

Lemma 1 (Equilibrium Profits in Price Competition)**.**

1. *For $c_L \in \{0, c\}$, $c_F = c$, and $c^e = \big(1-\hat{\theta}(m)\big)c$, the Bayesian Nash equilibrium profits in the Bertrand price competition game at stage 1 with asymmetric information are*

$$\pi_1^L(c_L, c|\hat{\theta}(m)) = \left[\frac{1}{2-\delta} + \frac{\delta^2 c^e - (4-\delta^2)\,c_L + 2\delta c}{2\,(2-\delta)\,(2+\delta)}\right]^2$$

and

$$\pi_1^F(c, c^e|\hat{\theta}(m)) = \left[\frac{1}{2-\delta} + \frac{\delta c^e - (2-\delta^2)\,c}{(2-\delta)\,(2+\delta)}\right]^2.$$

2. *For $c_L, c_F \in \{0, c\}$, the Nash equilibrium profits in the Bertrand price competition game at stage 2 with symmetric information are*

$$\pi_2^i(c_i, c_j) = \left[\frac{1}{2-\delta} + \frac{\delta c_j - (2-\delta^2)\, c_i}{(2-\delta)\,(2+\delta)}\right]^2$$

for $i = L, F$.

Observe that the leader's stage-1 payoffs increase in the follower's expectations of the leader's costs. As is a standard result for competition in strategic complements, higher expectations about the rival's costs render a firm's pricing less aggressive.[7] The leader therefore has an interest in making the follower believe she has high costs. Because the leader's announcement affects the follower's posterior belief, we can define the leader's benefits from concealing the pending patent (with posterior belief $\hat{\theta}(\varnothing)$) relative to announcing it (with poster belief $\hat{\theta}(A)$) follows:

$$\psi_A(\hat{\theta}(\varnothing), \hat{\theta}(A)) \equiv \pi_1^L(0, c|\hat{\theta}(\varnothing)) - \pi_1^L(0, c|\hat{\theta}(A)) \tag{7}$$

for the applicant and

$$\psi_0(\hat{\theta}(\varnothing), \hat{\theta}(A)) \equiv \pi_1^L(c, c|\hat{\theta}(\varnothing)) - \pi_1^L(c, c|\hat{\theta}(A)) \tag{8}$$

for the non-applicant. For $\hat{\theta}(A) = \hat{\theta}(\varnothing)$ we obtain $\psi_A = \psi_0 = 0$. Moreover, $\psi_A > 0$ and $\psi_0 > 0$ only if $\hat{\theta}(A) > \hat{\theta}(\varnothing)$. For the applicant, this ψ_A denotes her *value of secrecy* that is lost when the (secret) pending patent is announced.

We denote the follower's stage-2 benefit from innovation when he faces a non-applicant by

$$\psi_F \equiv \pi_2^F(0, c) - \pi_2^F(c, c). \tag{9}$$

From the expression for the follower's expected payoffs we see that, when the follower believes the leader is the high-cost type with certainty, then innovation (so that $r = 1$) increases his expected gross payoffs because $\psi_F > 0$. To establish some baseline innovation, we assume that when the follower faces a high-cost leader (producing under the status-quo technology), then he will always decide to innovate because his gross benefits of investment (with stage-2 weight α) more than compensate for the investment costs K:

Assumption 2. $\alpha\psi_F > K$.

Similarly, when the follower believes the leader is the low-cost type with certainty, then innovation increases his expected gross payoffs because $(1-\eta)\,\gamma\lambda > 0$. His gross benefits from innovation, $\alpha\,(1-\eta)\,\gamma\lambda$, in this case are equal to the savings from not having to pay license fees when his own technology does not infringe on the leader's patent.

4 Announcing Pending Patents

The equilibrium of the message-innovation game before product market competition in stage 1 depends on two key conditions. We first derive a sufficient condition for the applicant's announcement to have a deterring effect on the follower's innovation. This condition depends on the

[7] See Saloner (1987), Tirole (1988), or Ordover and Saloner (1989).

follower's expected benefits from innovation (i.e., his savings from innovation as the difference between the license payments when he innovates and when he does not innovate) and the costs of innovation. If costs are too low (relative to the benefits from innovation), then the follower always innovates irrespective of the applicant's behavior. If costs are too high, then the follower never innovates. These two scenarios are akin to the concepts of innovation *accommodation* and *blockade* as introduced by Bain (1956). If costs are intermediate (relative to the benefits from innovation), then the applicant's announcement is effective and have see a scenario of innovation *deterrence*. As a consequence, this sufficient condition for effectiveness is a necessary condition for the applicant to announce.

The second key condition determines if and when the applicant finds it profitable to announce the pending patent. Provided that announcing the pending patent is effective, we characterize three subsets of our parameter space that exhibit a separating equilibrium (in which the applicant announces with certainty), a mixed-strategy equilibrium, and a pooling equilibrium (in which the applicant never announces).

4.1 Equilibrium

We first derive the outcome of the firms' ex post license negotiations when the leader's patent has been granted (with probability γ) and the follower has not innovated (i.e., $r = 0$) or his new technology (when $r = 1$) is infringing on the leader's patent (with probability η). In any of these two cases, the firms enter license negotiations over license fee λ. For the firms' license negotiations, we assume Nash bargaining with equal weights:

Lemma 2. *If the applicant's patent application is granted and the firms enter license negotiations, the equilibrium license fee $\lambda = \lambda^*$ is*

$$\lambda^* = \frac{\alpha\,(1+\delta)\,[2-(1-\delta)\,c]\,c}{2\,(2-\delta)\,(2+\delta)}. \tag{10}$$

It increases in α (i.e., the market life expectancy of the technology), in δ (i.e., the degree of competition), and in c (i.e., the significance of innovation).

The realized license fee λ^* does not depend on the leader's announcement or the follower's innovation decision. The *expected* license fee, however, is a function of both m and r. More specifically, at the outset of the game at stage 0, the leader anticipates to receive license fee payments of

$$\begin{cases} \gamma\eta\lambda^* & \text{if follower innovates, } r(m) = 1 \\ \gamma\lambda^* & \text{if otherwise} \end{cases}$$

as a function of her announcement m by way of the follower's innovation decision. The follower, on the other hand, anticipates at stage 0 to pay expected license fees of

$$\begin{cases} \hat{\theta}(m)\gamma\eta\lambda^* & \text{if follower innovates, } r(m) = 1 \\ \hat{\theta}(m)\gamma\lambda^* & \text{if otherwise} \end{cases}$$

as a function of the leader's announcement by way of the follower's posterior belief $\hat{\theta}(m)$ that the leader is an applicant.

Before price competition in stage 1, the follower observes the leader's decision to announce a pending patent. He forms expectations about the leader's costs and the probability that he will pay the license fee. The follower innovates if the expected gross benefits from innovation, equal to $\Pi_F(m,1) - \Pi_F(m,0)$, cover the costs K. His expected payoffs $\Pi_F(m,r)$ for $r = 0,1$ are defined in equation (4). In other words, the follower invests if the expected net benefits of R&D investment, $R(m) \equiv \Pi_F(m,1) - \Pi_F(m,0) - K$, or equivalently,

$$R(m) = \alpha\big(\psi_F + \hat{\theta}(m)\,[(1-\eta)\,\gamma\lambda^* - \psi_F]\,\big) - K \tag{11}$$

are non-negative.

In Proposition 1 we show that if K is sufficiently low (of if the follower's benefits from innovation are sufficiently high), then announcing a pending patent is ineffective as it cannot deter the follower's innovation. As a consequence, the applicant does not announce her pending patent as she otherwise forego her value of secrecy at stage 1.

Proposition 1. *If $\alpha\,(1-\eta)\,\gamma\lambda^* \geq K$, then the applicant does not announce the pending patent, $m = \varnothing$, and the follower always innovates. Announcing a pending patent is ineffective for innovation deterrence.*

In Proposition 1, the sufficient condition for the announcement to deter the follower's innovation is violated. This condition is

$$R(\varnothing) \geq 0 > R(A). \tag{12}$$

It states that the follower innovates when $m = \varnothing$ but does not invest when $m = A$. Only when (12) is satisfied does the announcement $m = A$ have value to the leader. In all other cases, the follower's decision does not react to the announcement and the leader remains silent, $m = \varnothing$, to benefit from the stage-1 value of secrecy, ψ_A. More specifically, Proposition 1 discusses the case of $R(\varnothing) > R(A) \geq 0$. When, instead, $0 > R(\varnothing) > R(A)$, then the follower never innovates and the leader's announcement is not necessary.[8] We characterize the sufficient condition (12) as a function of the follower's benefits from innovation (i.e., the applicant's value of deterring innovation) in the following lemma.

Lemma 3. *The sufficient condition (12) for the applicant's announcement to deter the follower's innovation is*

$$\frac{K - \big(1-\hat{\theta}(\varnothing)\big)\alpha\psi_F}{\hat{\theta}(\varnothing)} \leq \alpha\,(1-\eta)\,\gamma\lambda^* < K \tag{13}$$

with $\dfrac{K - \big(1-\hat{\theta}(\varnothing)\big)\alpha\psi_F}{\hat{\theta}(\varnothing)} < K.$

Lemma 3 presents the sufficient condition for the applicant's announcement $m = A$ to deter the follower's innovation and also the necessary condition for the leader to be willing to announce her type. Without the ability to deter innovation, the negative effect of announcement on stage-1 profits prevails. In Proposition 1 we have presented the equilibrium outcome when the follower's

[8] Using the terminology introduced by Bain (1956) and following the discussion in Tirole (1988:306) in the context of entry, this is a situation of innovation *accommodation*, when innovation by the follower occurs irrespective of the leader's behavior.

benefits from innovation are so that he innovates irrespective of the announcement. In Proposition 2 we characterize the equilibrium when the follower's benefits from innovation are too low and he never innovates.[9]

Proposition 2. *If*

$$\frac{K - (1 - \theta)\alpha\psi_F}{\theta} > \alpha\,(1 - \eta)\,\gamma\lambda^*,$$

then the applicant does not announce the pending patent, $m = \varnothing$, and the follower does not innovate. Announcing a pending patent is not necessary for innovation deterrence.

Propositions 1 and 2 provide us with bounds on the applicant's value of deterring innovation (or, equivalently, the follower's benefits from innovation), $\alpha\,(1 - \eta)\,\gamma\lambda^*$, such that the applicant can influence the follower's innovation decision by announcing the pending patent. First, as in Proposotion 1, if $\alpha\,(1 - \eta)\,\gamma\lambda^* \geq K$, then the follower always innovates, irrespective of the applicant's decision. Second, as in Proposition 2, if

$$\alpha\,(1 - \eta)\,\gamma\lambda^* < \frac{K - (1 - \theta)\,\alpha\psi_F}{\theta},$$

then the follower never innovates, irrespective of the applicant's decision. Because

$$\frac{K - (1 - \theta)\,\alpha\psi_F}{\theta} < K,$$

there is always a value for $\alpha\,(1 - \eta)\,\gamma\lambda^*$ such that neither Proposition 1 nor Proposition 2 applies, and the sufficient condition in Lemma 3,

$$\frac{K - (1 - \theta)\,\alpha\psi_F}{\theta} \leq \alpha\,(1 - \eta)\,\gamma\lambda^* < K, \tag{14}$$

holds. For such intermediate values of $\alpha\,(1 - \eta)\,\gamma\lambda^*$, the follower's innovation decision depends on the applicant's announcement. In Proposition 3, we consider the subset of the parameter space such that condition (14) holds. We summarize how the leader strikes the balance between the negative effects of an announcement on her stage-1 equilibrium profits and the positive effects when an announcement deters the follower's innovation. In other words, the applicants juxtaposes the *value of secrecy*, $\psi_A(\hat{\theta}(\varnothing), 1)$, with the *value of deterring innovation*, $\alpha\,(1 - \eta)\,\gamma\lambda^*$.

Proposition 3 characterizes two pure-strategy equilibria. It also provides the range of parameters for which a pure-strategy equilibrium does not exist. The mixed-strategy equilibrium in this case is characterized in Proposition 4.

Proposition 3 (PBE in Pure Strategies)**.** *Let $\alpha\,(1 - \eta)\,\gamma\lambda^*$ such that condition (14) holds. The message-innovation game has the following perfect Bayesian equilibria in pure strategies: The follower innovates when $m = \varnothing$ and does not innovate when $m = A$. Moreover,*

1. *if $\alpha\,(1 - \eta)\,\gamma\lambda^* \geq \psi_A(0, 1)$, then the game has a separating equilibrium in which the applicant announces a pending patent with certainty (i.e., $\mu = 1$), so that $\hat{\theta}(\varnothing) = 0$ and $\hat{\theta}(A) = 1$; and*

[9] This is a scenario of innovation *blockade*, when the follower does not innovate irrespective of the leader's behavior (Bain, 1956; Tirole, 1988:306).

2. *if $\alpha\,(1-\eta)\,\gamma\lambda^{*} \leq \psi_A(\theta,1)$, then the game has a pooling equilibrium in which the applicant does not announce a pending patent (i.e., $\mu = 0$), so that $\hat{\theta}(\varnothing) = \theta$ and $\hat{\theta}(A) = 1$.*

If the follower's prior belief θ is such that $\psi_A(\theta,1) < \alpha\,(1-\eta)\,\gamma\lambda^{*} < \psi_A(0,1)$, then a pure-strategy equilibrium does not exist.

With the value of deterring innovation such that a pure-strategy equilibrium does not exist,

$$\psi_A(\theta,1) < \alpha\,(1-\eta)\,\gamma\lambda^{*} < \psi_A(0,1), \tag{15}$$

the value of secrecy is too low for the applicant to remain silent but too high for the applicant to announce the pending patent. In Proposition 4 we characterize a mixed-strategy equilibrium for this case in which the applicant randomizes (i.e., chooses a mixed-strategy $\mu \in (0,1)$) such that the posterior belief $\bar{\theta}(\mu) = \frac{\theta(1-\mu)}{1-\theta\mu}$ equate the value of deterring innovation and the value of secrecy.

Proposition 4 (PBE in Mixed Strategies)**.** *Let $\alpha\,(1-\eta)\,\gamma\lambda^{*}$ such that both conditions (14) and (15) hold. The message-innovation game has the following perfect Bayesian equilibrium in mixed strategies (hybrid equilibrium): The follower innovates when $m = \varnothing$ and does not innovate when $m = A$. Moreover, the applicant announces a pending patent with probability μ^{*} such that*

$$\alpha\,(1-\eta)\,\gamma\lambda^{*} = \psi_A\Big(\frac{\theta\,(1-\mu^{*})}{1-\theta\mu^{*}},1\Big).$$

The follower's equilibrium belief, given the leader's mixed strategy $\mu^{*} = Pr(m = A|L = L_A)$, is $\hat{\theta}(\varnothing) \in (0,\theta)$ and $\hat{\theta}(A) = 1$. The mixed strategy μ^{*} increases in α, γ, and λ^{*} and decreases in η.

Recall that if condition (14) does not hold, then an announcement $m = A$ has no effect on the follower's innovation decision and the applicant will stay silent on the matter. If the condition holds, then announcing a pending patent deters the follower's innovation. Whether such deterrence is profitable for the applicant depends on the value of secrecy, ψ_A, relative to the value of deterring innovation, $\alpha\,(1-\eta)\,\gamma\lambda^{*}$. Proposition 3 characterizes the equilibria when condition (15) is violated, and in Proposition 4 we characterize the mixed-strategy equilibrium when the condition holds. In the sequel, we discuss these equilibria and the comparative statics with respect to our parameters of interest.

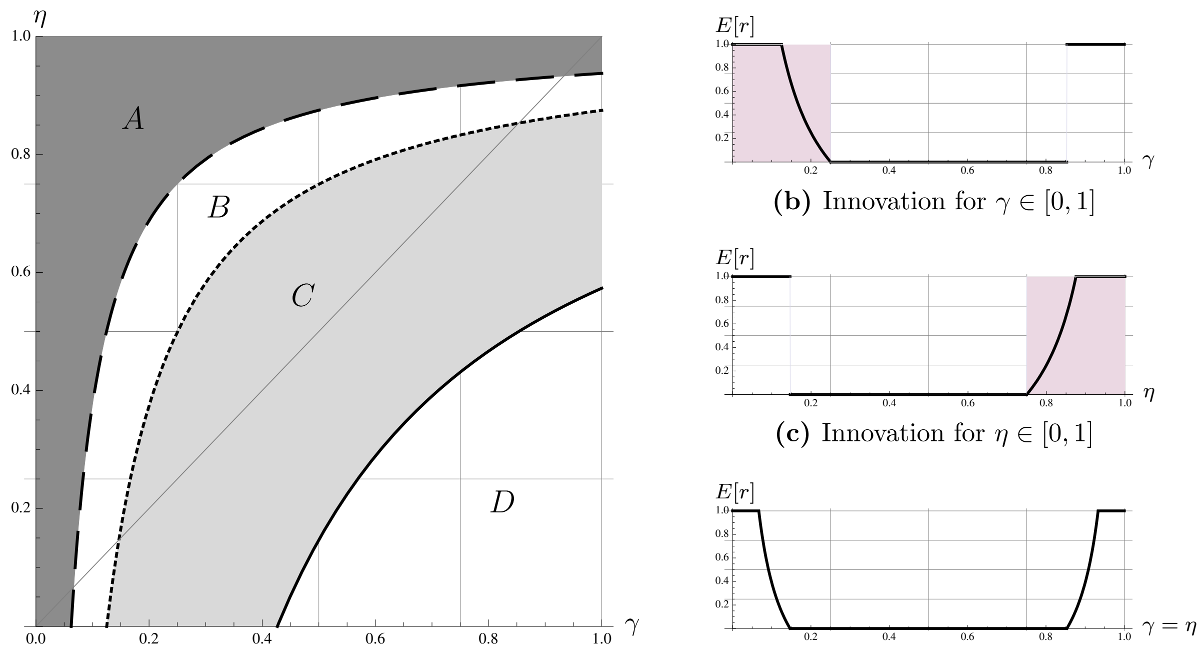
4.2 Discussion of Results

We discuss the comparative statics of our equilibrium results with respect to three set of parameters. First, we consider application strength γ and patent strength η. Second, we present the results for technology specific parameters α (market life expectancy), c (significance of innovation), and K (innovation costs K). And third, we present the results for industry and firm specific parameters δ (degree of competition) and θ (follower's prior belief).

4.2.1 Application Strength and Patent Strength

As application strength γ increases and patent strength (or probability of infringement) η decreases, the applicant's value of deterring innovation, $\alpha\,(1-\eta)\,\gamma\lambda^{*}$, increases. Given the critical values in conditions (14) and (15) (independent of either γ or η), we obtain different regions in the (γ,η)-space with different types of equilibria.

Figure 2: Equilibria and Expected Innovation for γ and η



(a) PBE Equilibria in (γ, η)-space

(b) Innovation for $\gamma \in [0, 1]$

(c) Innovation for $\eta \in [0, 1]$

(d) Innovation for $\gamma = \eta \in [0, 1]$

Notes: Panel (a) depicts the perfect Bayesian equilibria in (γ, η)-space for sufficiently low K so that $\theta \geq \omega(\gamma, \eta)$ for all γ and all η and the equilibrium in Proposition 2 does not apply. Parameter values are $\alpha = 1$, $c = 1/4$, $K = 1/25$, $\delta = 1/2$, and $\theta = 1/2$. For (γ, η) captured by the lower right corner (area D), the results in Proposition 1 apply; for (γ, η) in the shaded areas the pure-strategy equilibrium results in Proposition 3 apply (dark gray area A depicts the pooling equilibrium, light gray area C depicts the separating equilibrium); the white area B in between the shaded areas depicts the mixed-strategy equilibrium in Proposition 4. Panels (b) and (c) depict the expected equilibrium innovation as function of γ and η, where $E[r] \in [0, 1]$ is the probability that the follower innovates. For panel (b), $\eta = 1/2$; for panel (c), $\gamma = 1/2$; for panel (d), $\gamma = \eta$. For γ and η in Proposition 1 and the pooling equilibrium in Proposition 3, the follower innovates so that $E[r] = 1$; for γ and η in the separating equilibrium in Proposition 3, the follower does not innovate and $E[r] = 0$. For γ and η in the mixed-strategy equilibrium in Proposition 4, the follower innovates only if the applicant does not announce the pending patent, i.e., with probability $E[r] = 1 - \mu^*$.

In Panel (a) of Figure 2 we illustrate the regions of equilibria for a low enough value of K such that $\alpha\,(1-\eta)\,\gamma\lambda^* \geq \frac{K-(1-\theta)\alpha\psi_F}{\theta}$ so that the results in Proposition 2 do not apply. For the illustration we further assume that $K > \psi_A(0,1)$ and $\alpha\,(1-\eta)\,\gamma\lambda^* > K$ for high γ (low η) and $\alpha\,(1-\eta)\,\gamma\lambda^* < \psi_A(\theta,1)$ for low γ (high η). The solid curve depicts (γ, η) such that $\alpha\,(1-\eta)\,\gamma\lambda^* = K$, and for all (γ, η) to the lower right of that curve (area D) the equilibrium results in Proposition 1 apply. The dotted and the dashed curves depict (γ, η) such that $\alpha\,(1-\eta)\,\gamma\lambda^* = \psi_A(0,1)$ and $\alpha\,(1-\eta)\,\gamma\lambda^* = \psi_A(\theta,1)$ from Proposition 3. The dark-shaded area A represents the pooling equilibrium, and the light-shaded area C represents the separating equilibrium. The white area B in between represents the mixed-strategy equilibrium in Proposition 4.

For low application strength γ, an increase in γ will initially reduce innovation. Given any η, the applicant does not find it profitable to deter innovation and does therefore not announce the pending patent when γ is low. The follower then innovates (i.e., pooling equilibrium, A). As γ increases, the applicant announces with increasing probability μ^*, inducing the follower to innovate less often (i.e., mixed-strategy equilibrium, B). For intermediate values of γ, the applicant's value of deterring innovation now exceeds her value of secrecy and she announces the pending patent. This in return deters the follower's innovation (i.e., separating equilibrium, C). For even stronger applications (with higher values of γ), however, the applicant's announcement is not effective and the follower innovates irrespective of the applicant's decision. This is because for high values of γ (given low enough η), the follower's benefits from innovation always outweigh the costs (area D).

The pattern for the patent strength η is analogous. Given high enough application strength (e.g., $\gamma = 1/2$), for low η the applicant's patent is expected to be weak (i.e., the follower does not expect his innovation to infringe on the applicant's patent very often) and the follower's benefits from innovation are high. Again, the applicant's announcement cannot affect the follower's innovation decision (area D). As the patent grows stronger and η increases, the follower's benefits from innovation decrease, and for intermediate values of η, the applicant finds it profitable to deter innovation by announcing the pending patent (i.e., separating equilibrium, C). As η increases even further, the applicant announces with decreasing probability μ^*, and the follower innovates more often (i.e., mixed-strategy equilibrium, B). For high values of patent strength η, the applicant does not want to deter innovation. She anticipates that with a very strong patent (i.e., a high probability of infringement by the follower) she will be able to extract license fees from the follower with high enough a probability and effectively chooses to encourage the follower's innovation by not announcing the pending patent (i.e., pooling equilibrium, A).

In Panels (b) and (c) of Figure 2 we plot the follower's expected innovation as a function of application strength γ and patent strength η. This relationship between innovation in γ and η is non-monotonic for intermediate values of K. In other words, as long as K is low enough so that

$$\frac{K - (1-\theta)\,\alpha\psi_F}{\theta} < \psi_A(0,1)$$

and high enough so that

$$\psi_A(\theta,1) < K,$$

expected innovation is not monotonically increasing in application strength γ and not monotonically decreasing in patent strength η.

The non-monotonicity also holds in the scenario of perfect correlation of γ and η. This is the case when a strong patent application implies a strong patent, and vice versa. In Panel (d) of Figure 2 we plot the follower's expected innovation as a function of γ when $\eta = \gamma$.

4.2.2 Market Life Expectancy

The parameter α captures the market life expectancy or the expected shelf life of the respective technology generation. In Panel (a) of Figure 3 we vary α. For sufficiently low α, we have $\alpha\,(1-\eta)\,\gamma\lambda^* < \frac{K-(1-\theta)\alpha\psi_F}{\theta}$ so that the results in Proposition 2 apply for (γ,η) in the upper left corner of the first graph. At the same time, $\alpha\,(1-\eta)\,\gamma\lambda^* \leq K$ for all γ and η so that the results in Proposition 1 do not apply in the first graph. The second graph is the same as in Figure 2. As α increases, the border lines in the graphs shift to the upper left. This means that the condition in Proposition 1 holds for a wider range of (γ,η), implying that innovation deterrence by means of an announcement of a pending patent is effective less often. As the market life expectancy, α, increases we expect to see more innovation and fewer pending patent announcements.

4.2.3 Significance of Innovation

The parameter c captures the significance of innovation. In Panel (b) of Figure 3 we vary c. As c increases, the bounds in condition (14) shift to the upper left, whereas the bounds in condition (15) shift to the lower right.

4.2.4 Innovation Costs

The parameter K captures the costs of the follower's innovation. In Panel (c) of Figure 3 we vary K. As K increases, the bounds in condition (14) shift to the lower right, and the bounds in condition (15) are not affected.

4.2.5 Degree of Competition

The parameter δ captures the degree of competition. In Panel (a) of Figure 4 we vary δ. As δ increases, the bounds in condition (14) shift to the upper left, whereas the bounds in condition (15) shift to the lower right.

4.2.6 Follower's Prior Beliefs

The parameter θ captures the follower's prior belief that the leader is an applicant. In Panel (b) of Figure 4 we vary θ. As δ increases, the bound in the condition in Proposition 2 shifts to the lower right, and the condition for the pooling equilibrium in Proposition 3 shifts to the upper left.

5 Concluding Remarks

In many jurisdictions, the existence and contents of patent applications are unknown to third parties until the application is published by the patent office at least 18 months after the initial filing. The patent applicant can expedite this public awareness of the existing application and the respective technology by announcing the patent application before its automatic publication. We study this decision in a model that captures the inter-temporal trade-off an applicant faces. On the one hand, an announcement of a pending patent application informs a firm's rival of potential intellectual property, and this awareness can deter the rival's own innovation. On the other hand, a patent application does not only hold information about the technology for which patent protection is sought. The fact that a patent has been applied can convey information about the a firm's business and technology management and the composition of its patent portfolio. Disclosing some of this information can have immediate (or short-run consequences).

In our model, the applicant balances this negative effect of disclosure on its informational advantage in the short run (*value of secrecy*) with a positive long-run effect stemming from potential deterrence of a rival's R&D (*value of deterring innovation*). We give conditions under which announcing the pending patent deters a rival's innovation. We show that, in equilibrium, the applicant's decision to announce and the rival's decision to innovate are non-monotonic in the strength of the application and the strength of the patent. This implies that stronger intellectual property rights do not always deter innovation when an applicant does not find it profitable to inform a rival of its pending status.

Appendix

A Formal Proofs of Results

Proof of Lemma 1. Formal steps to derive (Bayesian) Nash equilibria in a Bertrand price competition game can be found, e.g., in Tirole (1988) or Vives (1999). A formal proof is therefore omitted and left for the reader. Q.E.D.

Proof of Lemma 2. First, note that if the firms do not agree on a license fee, then their disagreement point payoffs are $d_L = \alpha\pi_2^L(0, c)$ and $d_F = \alpha\pi_2^F(c, 0)$. If they do agree on a license and the follower is allowed to use the leader's patented technology, their second-stage profits from price competition are $\alpha\pi_2^L(0, 0)$ and $\alpha\pi_2^F(0, 0)$. The equilibrium license fee λ^* as a transfer from the follower to the leader maximizes the Nash product:

$$\lambda^* = \arg\max_{\lambda} \left[\alpha\pi_2^L(0,0) + \lambda - d_L\right]^{1/2} \cdot \left[\alpha\pi_2^F(0,0) - \lambda - d_F\right]^{1/2}. \tag{A1}$$

The equilibrium license fee satisfies

$$\left[\frac{\alpha\pi_2^F(0,0) - \lambda - d_F}{\alpha\pi_2^L(0,0) + \lambda - d_L}\right]^{1/2} = \left[\frac{\alpha\pi_2^L(0,0) + \lambda - d_L}{\alpha\pi_2^F(0,0) - \lambda - d_F}\right]^{1/2} \tag{A2}$$

Solving for λ and simplifying terms, we obtain

$$\lambda^* = \frac{\alpha\,(1+\delta)\,[2 - (1-\delta)\,c]\,c}{2\,(4-\delta^2)}. \tag{A3}$$

This expression is strictly positive if $c > 0$ and $c < \frac{2}{1-\delta}$ which holds true by Assumption 1. Straightforward algebra establishes the comparative statics result. Q.E.D.

Proof of Proposition 1. Observe that $R(m)$ increases in the follower's posterior belief $\hat{\theta}(m)$ if

$$(1-\eta)\,\gamma\lambda^* > \psi_F,$$

that is, if the follower's savings from not having to obtain a license when its own technology does not infringe on the leader's patent are greater than his stage-2 benefits from innovation when he faces a non-applicant. In this case, the follower's expected net benefits are higher when he expects the leader to be the low-cost type with a pending patent, and by announcing her pending patent the leader makes innovation more profitable for the follower. Formally, if $(1-\eta)\,\gamma\lambda^* > \psi_F$, then $\hat{\theta}(A) > \hat{\theta}(\varnothing)$ implies $R(A) > R(\varnothing)$. Announcing the pending patent has therefore a two-fold negative effect on the leader's expected profits. First, the leader's expected payoffs $\Pi_A(m)$ in equation (5) and $\Pi_0(m)$ in equation (6) are directly affected by the follower's innovation decision and are lower for innovation than no innovation. And second, because $\hat{\theta}(A) = 1 > \hat{\theta}(\varnothing)$, the leader's *value of secrecy* (i.e., the benefits ψ_L in equations (7) and (8) from concealing the pending patent) are positive. Announcing the pending patent has therefore negative effects on the leader's stage-1 profits. As a result, when $(1-\eta)\,\gamma\lambda^* \geq \psi_F$, the leader does not announce the pending patent, and the follower always innovates.

If, alternatively, $(1-\eta)\,\gamma\lambda^* < \psi_F$, then $R(m)$ decreases in the follower's posterior belief. However, for sufficiently low innovation costs K, the follower innovates irrespective of the leader's announcement. To see this, first note that for $(1-\eta)\,\gamma\lambda^* < \psi_F$ we have $R(\varnothing) > R(A)$ because $\hat{\theta}(A) = 1 > \hat{\theta}(\varnothing)$. Then, for $m = A$ and $\hat{\theta}(A)$, the follower's expected net benefits are $R(A) \geq 0$ if $\alpha\,(1-\eta)\,\gamma\lambda^* \geq K$. In this case, the follower always innovates, that is, $R(\varnothing) > R(A) \geq 0$. The leader therefore does not announce the pending patent and the follower always innovates.

Because $\alpha\psi_F > K$ by Assumption 2, if $\alpha\,(1-\eta)\,\gamma\lambda^* \geq K$, then $m = \varnothing$ and the follower innovates. Q.E.D.

Proof of Lemma 3. Rearranging $R(\varnothing) \geq 0$ and $R(A) < 0$ yields the condition in the lemma. The second claim is by Assumption 2. Q.E.D.

Proof of Proposition 2. If

$$\frac{K - (1-\theta)\,\alpha\psi_F}{\theta} > \alpha\,(1-\eta)\,\gamma\lambda^*, \tag{A4}$$

then $0 > R(\varnothing) > R(A)$. As a consequence, the follower does not innovate. The applicant does not announce, $m = \varnothing$ in order to not forego the value of secrecy. This implies $\hat{\theta}(\varnothing) = \theta$. Q.E.D.

Proof of Proposition 3. Recall that the action set for the high-cost leader is a singleton, $M_0 = \{\varnothing\}$. For the proof we therefore do not need to consider the high-cost leader's incentives but limit our attention to the low-cost leader's actions.

1. In a separating equilibrium, the low-cost leader announces a pending patent, $m = A$ and $\mu = 1$, so that $\hat{\theta}(\varnothing) = 0$ and $\hat{\theta}(A) = 1$. Her payoffs for $m = A$, so that innovation is deterred by Lemma 3, are

$$\pi_1^L(0, c|1) + \alpha\left[\pi_2^L(0,0) + \gamma\lambda^*\right]. \tag{A5}$$

If she deviates so that instead $m = \varnothing$, then $\hat{\theta}(\varnothing) = 0$. In this case, $R(\varnothing) > 0$ and the follower innovates. The leader's payoffs from $m = \varnothing$ are then

$$\pi_1^L(0, c|0) + \alpha\left[\pi_2^L(0,0) + \eta\gamma\lambda^*\right]. \tag{A6}$$

After some rearranging we find that the low-cost leader has no incentive to deviate from $m = A$ if

$$\alpha\,(1-\eta)\,\gamma\lambda^* \geq \psi_A(0,1) > 0. \tag{A7}$$

with $\psi_A(0,1)$ defined in equation (7). In other words, the low-cost leader announces the pending patents in equilibrium as long as her value of deterring innovation is at least as high as the value of secrecy (when she does not announce off equilibrium so that the follower's beliefs are $\hat{\theta}(\varnothing) = \theta$).

2. In a pooling equilibrium, the low-cost leader does not announce a pending patent, $m = \varnothing$ so that $\hat{\theta}(\varnothing) = \theta$. If she announces the pending patent off the equilibrium path, then $\hat{\theta}(A) = 1$ because only the low-cost leader can announce a pending patent. The leader's payoffs from $m = \varnothing$, so that the follower innovates by Lemma 3, are

$$\pi_1^L(0, c|\theta) + \alpha\left[\pi_2^L(0,0) + \eta\gamma\lambda^*\right]. \tag{A8}$$

If she deviates from $m = \varnothing$ and instead announces, $m = A$, then $\hat{\theta}(A) = 1$, so that the follower does not innovate, and her payoffs are as given in equation (A5). After some rearranging we find that the low-cost leader has no incentive to deviate from $m = \varnothing$ if

$$\alpha\,(1-\eta)\,\gamma\lambda^* \leq \psi_A(\theta, 1). \tag{A9}$$

In other words, the low-cost leader does not announce the pending patents in equilibrium if her value of deterring innovation (when she announces off equilibrium) is at least as low as the value of secrecy with follower's equilibrium beliefs $\hat{\theta}(\varnothing) = \theta$).

Because $\psi_A(\hat{\theta}(\varnothing), \hat{\theta}(A)) = \psi_A(\hat{\theta}(\varnothing), 1)$ decreases in $\hat{\theta}(\varnothing)$, for sufficiently high θ we have $\alpha\,(1-\eta)\,\gamma\lambda^* > \psi_A(\theta, 1)$. For instance, for $\theta = 1$ we obtain $\psi_A(1, 1) = 0$ which is strictly less than $\alpha\,(1-\eta)\,\gamma\lambda^*$ for $\alpha > 0$, $\eta < 1$, and $\gamma > 0$. Moreover, for sufficiently low α, sufficiently high η, and sufficiently low γ we obtain $\alpha\,(1-\eta)\,\gamma\lambda^* < \psi_A(0, 1)$. We then have a non-empty subset of our parameter space for which a pure-strategy equilibrium does not exist. Q.E.D.

Proof of Proposition 4. Because

$$\frac{K - (1-\theta)\,\alpha\psi_F}{\theta}$$

increases in θ, if

$$\frac{K - (1-\theta)\,\alpha\psi_F}{\theta} \leq \alpha\,(1-\eta)\,\gamma\lambda^*,$$

then it holds for any $\mu > 0$ so that $\hat{\theta}(\varnothing) < \theta$. This means that the follower innovates if $m = \varnothing$ and does not innovate if $m = A$. From the proof in Proposition 3 we recall that if $\psi_A(\theta, 1) < \alpha\,(1-\eta)\,\gamma\lambda^* < \psi_A(0, 1)$, then there is no pure-strategy equilibrium if $\mu = 0, 1$. A μ with the follower's posterior beliefs

$$\bar{\theta}(\mu) = \frac{\theta\,(1-\mu)}{1-\theta\mu} \tag{A10}$$

render the value of deterring innovation (when $m = A$) equal to the value of secrecy (when $m = \varnothing$ with posterior belief $\bar{\theta}(\mu)$) so that

$$\alpha\,(1-\eta)\,\gamma\lambda^* = \psi_A(\frac{\theta\,(1-\mu)}{1-\theta\mu}, 1).$$

The applicant's expected payoffs from this mixed strategy $\mu^* \in (0, 1)$ are at least as high as the payoffs from a pure strategy $m = \varnothing, A$. To see this, first note that if the applicant announces the pending patent with probability μ^*, then the follower will not innovate with probability μ^*. The applicant's expected payoffs from the mixed strategy are

$$\begin{aligned}
\bar{\Pi}_A(\mu^*) &= \mu^* \left\{\pi_1^L(0, c|1) + \alpha\left[\pi_2^L(0, 0) + \gamma\lambda^*\right]\right\} + \\
&\quad (1-\mu^*)\left\{\pi_1^L(0, c|\bar{\theta}(\mu^*)) + \alpha\left[\pi_2^L(0, 0) + \eta\gamma\lambda^*\right]\right\} \\
&= \pi_1^L(0, c|\bar{\theta}(\mu^*)) + \alpha\left[\pi_2^L(0, 0) + \eta\gamma\lambda^*\right] - \mu^*\left\{\psi_A(\bar{\theta}(\mu^*), 1) - \alpha\,(1-\eta)\,\gamma\lambda^*\right\}.
\end{aligned} \tag{A11}$$

To show that these expected payoffs are at least as high as the applicant's payoffs for $\mu = 0$, we show that $\bar{\Pi}_A(\mu^*) \geq \bar{\Pi}_A(0)$. Recall that for $\mu = 0$, the follower innovates when $m = \varnothing$. After some rearranging the condition can then be rewritten as

$$\psi_A(\bar{\theta}(\mu^*), \theta) - \mu^* \left\{ \psi_A(\bar{\theta}(\mu^*), 1) - \alpha (1 - \eta) \gamma \lambda^* \right\} \geq 0 \tag{A12}$$

where the term in braces is equal to zero by the definition of μ^* and $\psi_A(\bar{\theta}(\mu^*), \theta) \geq 0$ because $\bar{\theta}(\mu^*) \leq \theta$ for all μ^*. Next, to show that the expected payoffs under mixed strategy μ^* are at least as high as the applicant's payoffs for $\mu = 1$, we show that $\bar{\Pi}_A(\mu^*) \geq \bar{\Pi}_A(1)$. First, recall that for $\mu = 1$, the follower never innovates. After some rearranging the condition can then be rewritten as

$$(1 - \mu^*) \left\{ \psi_A(\bar{\theta}(\mu^*), 1) - \alpha (1 - \eta) \gamma \lambda^* \right\} \geq 0 \tag{A13}$$

because the term in braces is equal to zero by definition of μ^*.

For the comparative statics of μ^*, first note that $\bar{\theta}(\mu)$ decreases in μ and $\psi_A(\theta, 1)$ decreases in θ so that $\psi_A(\bar{\theta}(\mu), 1)$ increases in μ. As a consequence, if the LHS of the defining condition for μ^* increases, then the RHS must increase, implying that μ^* must increase. Because the LHS increases in α (directly and through the effect of α on λ^*), γ, and λ^*, the mixed strategy μ^* increases in these parameter. Moreover, because the LHS of the defining condition decreases in η, the mixed strategy μ^* decreases in η. Q.E.D.

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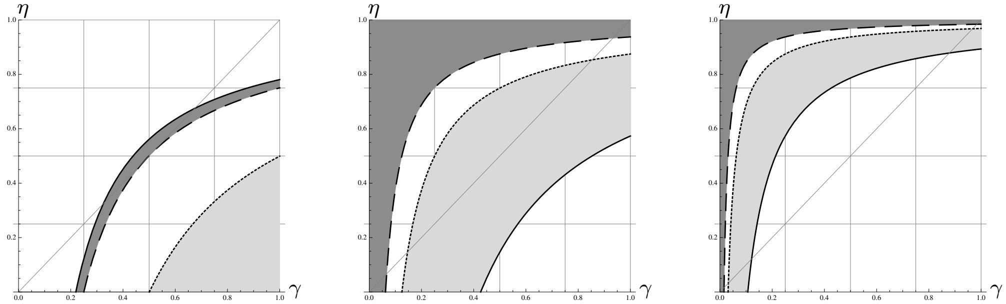
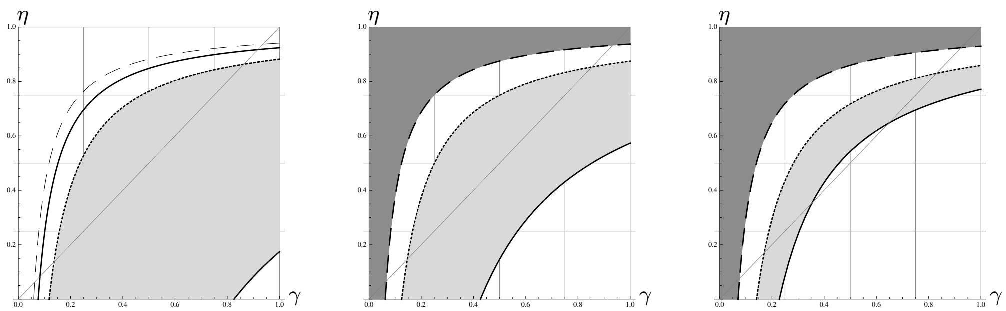
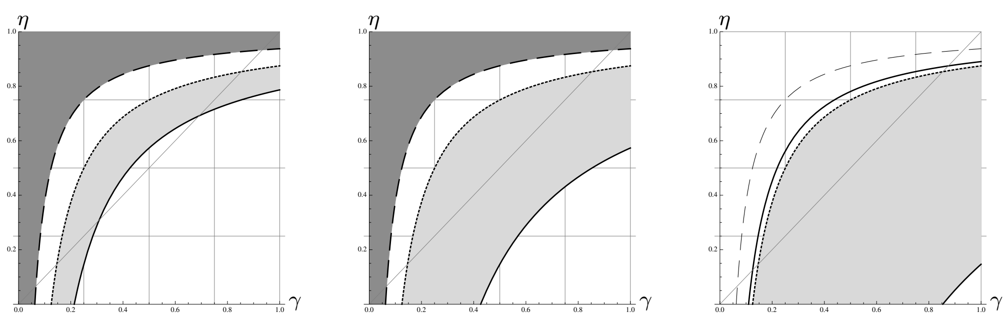
Figure 3: Equilibria for Technology Specific Parameters



(a) Technology Life Cycle α



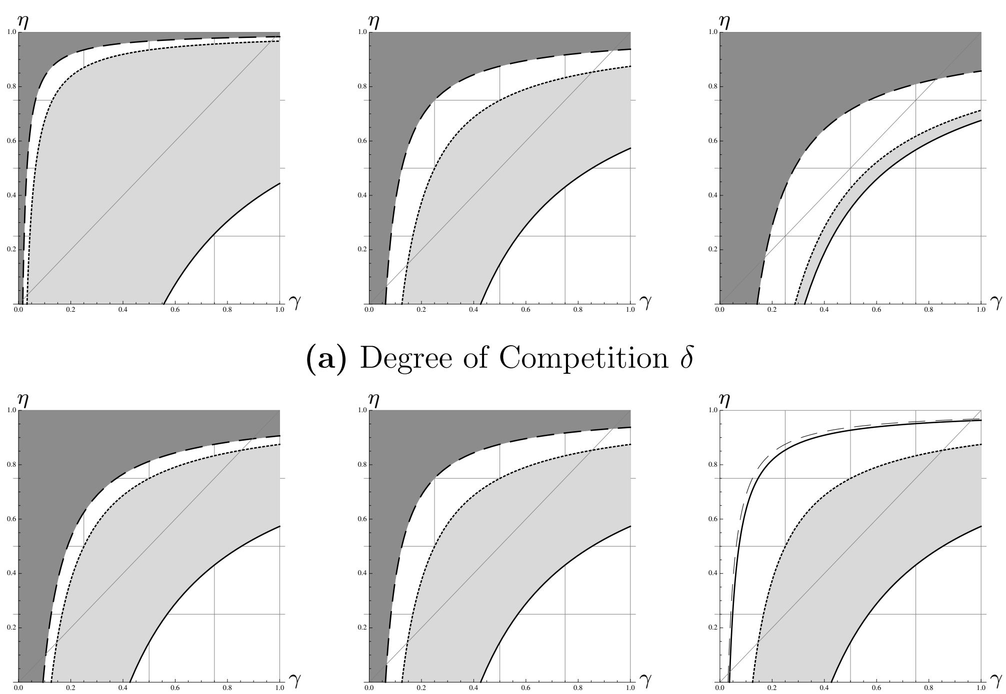
(b) Significance of Innovation c



(c) Innovation Costs K

Notes: For Panel (a), $\alpha \in \{1/2, 1, 2\}$; for Panel (b), $c \in \{1/8, 2/8, 4/8\}$; for Panel (c), $c \in \{1/50, 2/50, 4/50\}$. All other parameters are as in Figure 2.

Figure 4: Equilibria Industry and Firm Specific Parameters



(a) Degree of Competition δ

(b) Follower's Prior Beliefs θ

Notes: For Panel (a), $\delta \in \{1/4, 1/2, 3/4\}$; for Panel (b), $\theta \in \{1/4, 1/2, 3/4\}$. All other parameters are as in Figure 2.