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Competition and the Strategic Disclosure of Innovation: Theory and Evidence from Patent Applications

David T. Angenendt[1]
Bernhard Ganglmair[2]

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[1]Technical University of Munich and University of Cambridge Email : david.angenendt@gmail.com
[2]University of Mannheim and ZEW, Email : b.ganglmair@gmail.com

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Competition and the Strategic Disclosure of Innovation: Theory and Evidence from Patent Applications*

David T. Angenendt† Bernhard Ganglmair‡

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Abstract

We develop a duopoly signaling model in which an innovative leader strategically announces a pending patent application to influence the follower's behavior, both in the product market (in the short run) and in R&D (with effects in the long run). Our model captures different competitive structures by representing market competition in reduced form, thereby encompassing competition in both strategic substitutes and strategic complements with varying intensities. Extending the conventional wisdom of the optimality of disclosure under strategic substitutes, our model predicts some disclosure for low competition intensities under strategic complements when the follower's R&D project is technologically less similar to the leader's, and no disclosure even under strategic substitutes when competitors' R&D exhibits high similarities. We provide empirical support for the model's core predictions by identifying patent disclosures in press releases and using a technique from the corporate finance literature to measure the nature of market competition.

Key words: information disclosure, innovation, IP management, patenting, pending patents, R&D.

JEL classification: D82, L13, O31, O34

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†Technical University of Munich, TUM School of Management, and University of Cambridge, Centre for Business Research. E-mail: david.angenendt@gmail.com.

‡University of Mannheim and ZEW Mannheim. E-mail: b.ganglmair@gmail.com.

1 Introduction

Ample survey-based evidence suggests that secrecy is at or near the top of the list of firms' strategies to protect new inventions and ideas, more widely used and popular than formal protection through, for instance, patents (e.g., Levin et al., 1987; Cohen et al., 2000; Arundel, 2001). Moreover, more recent causal empirical results document (proprietary) costs of disclosures for firms when facing mandatory disclosure policies (e.g., Kim and Valentine, 2021). Still, it is common practice among firms to publicly announce their technological breakthroughs.

> *SALEM, NH – (Marketwired - May 14, 2015) – ProPhotonix Limited, a designer and manufacturer of LED illumination systems and laser diode modules [. . .] today announces that it has filed a patent application on its unique heat sink for optical modular array assemblies. . . .*

> *Vancouver, British Columbia – (Newsfile Corp. - September 30, 2015) – PyroGenesis Canada has filed a provisional patent for a one step process using plasma arc for producing high purity silicon from silica. . . .*

ProPhotonix and PyroGenesis are but two examples of firms that disclosed, via press releases, the existence of pending patent applications, potentially providing competitors with previously unknown information.[1] Firms may choose such a disclosure strategy signal to financial markets a good investment when seeking start-up funding (Cockburn and MacGarvie, 2009; Haeussler, Harhoff, and Mueller, 2009; Hottenrott, Hall, and Czarnitzki, 2016; Mohammadi and Khashabi, 2021).[2] Founded in 1951 and 1991, respectively, the start-up funding explanation applies to neither ProPhotonix nor PyroGenesis. Gunderman and Hammond (2007), in a practitioner's guide, highlight the product-market opportunities of the firm's disclosure decision.

> *"When your competitors see the words [pending patents] . . . they will naturally wonder about the scope of your patent application . . . So your competitor's fear of*

[1]The press releases: https://finance.yahoo.com/news/prophotonix-announces-patent-application-060000971.html (last accessed: March 10, 2025) and https://www.newsfilecorp.com/release/17480/PyroGenesis-Canada-Files-Provisional-Patent-for-Using-Plasma-Arc-to-Produce-High-Purity-Silicon-from-Silica-Video-News-Alert-on-InvestmentPitch (last accessed: March 10, 2025).

[2]Other explanations in the literature are a signal to consumers the quality of the invention (Hsu and Ziedonis, 2013), the conveying of a certain reputation (Graham et al., 2009), or the attempt to improve one's bargaining position in license negotiations (Hall and Ziedonis, 2001).

the unknown may provide you a temporary but substantial advantage in the marketplace."

We take inspiration from this "fear of the unknown" and ask which product-market environments and technology spaces are conducive for such a strategy? When do firms find it profitable to disclose to competitors the existence (and prospective patent protection) of a new invention or technology?

To answer this question, we propose a signaling model that captures a simple trade-off. On the one hand, an announcement of a pending patent application by a technology leader can deter innovation by a follower (e.g., Glaeser and Landsman, 2021). The announcement informs the leader's rival of its successful innovation project (with imperfectly enforced intellectual property) and serves as a signal allowing the follower to update the success probability of her own R&D projects. This signal deters the follower's R&D as long as it does not make her too optimistic about her R&D prospects. An announcement can, therefore, have positive effects on the leader in the long run when the follower does not become a competitor in the technology space. On the other hand, a patent application not only holds information about the technology for which patent protection is sought (with potential implications for follower's R&D), but it may also reveal details about a firm's product-market behavior. To operationalize such short-run *proprietary costs* of disclosure (e.g., Kim and Valentine, 2021), we develop a reduced-form competition model with incomplete information that nests competition models both in strategic substitutes and complements (with varying intensities) and captures the disclosure incentives through a single parameter. Classic results in economics (e.g., Gal-Or, 1986) find disclosure in competition environments with strategic substitutes; and no disclosure in environments with strategic complements.

Combining the short-term effects of the announcement signal on the product market with its long-run effects on follower's R&D (and the technology space), we obtain a more nuanced set of results and richer predictions. When the firms' R&D prospects are not highly correlated, an announcement of a pending patent application can deter the follower's R&D (because the costs of infringing on the leader's patent if and when it is granted outweigh the benefits of an alternative technology). In this case, and to trigger these long-term benefits from disclosure, the technology leader announces the patent application even when competition is in strategic complements (at sufficiently low intensity) and a standard, non-innovation model predicts non-disclosure (Proposition 1 in pure strategies; Proposition 2 in mixed strategies). The standard results in, for instance, Gal-Or (1986) apply in an intermediate range of R&D correlation (Proposition 3). Last, when the firms' R&D are highly correlated, then an announcement can trigger the follower's R&D as she becomes optimistic about her own R&D success. In this case, the leader will not announce even when competition is in strategic substitutes (at sufficiently low intensity) (Proposition 4).

We present empirical evidence supporting the core predictions of our model using press releases on patent application filings by U.S. firms as our outcome variable (i.e, the leader's announcement). We are thus able to provide empirical support for the theoretical predictions going back to Gal-Or (1986), Darrough (1993), and Hughes and Pae (2015) that production cost disclosure depends on the mode of competition in an industry. We measure the (industry-level) nature of competition (i.e., strategic complements or substitutes) using the approach in Kedia (2006) and use the data on firm-pair product-market similarities by Hoberg and Phillips (2016) to proxy R&D correlation. Our empirical results confirm the theoretical predictions: We observe more disclosure-related press releases in industries that are characterized by competition in strategic substitutes and that exhibit low R&D correlation.

The structure of the paper is as follows. We summarize the relevant literature and contextualize our results in Section 2. We introduce our model in Section 3 and characterize equilibria in Section 4. We discuss comparative statics and derive testable predictions in Section 5. We present details of our data construction and empirical results in Section 6. In Section 7, we conclude. The formal proofs of our theoretical results are relegated to the Appendix.

2 Related Literature

Information Sharing in Oligopoly. A well-established literature examines firms' incentives to disclose private information about marginal production costs in quantity-setting duopolies (Fried, 1984; Shapiro, 1986).[3] Gal-Or (1986) showed that disclosure incentives depend on the nature of competition: When the slope of reaction functions reverses, so do the incentives for disclosure. Our model extends this literature by framing cost disclosure as the public announcement of pending patents, with Gal-Or's results as a special case. To the best of our knowledge, our empirical analysis provides the first direct evidence supporting this literature's predictions. A related strand of research examines sharing of private information (signals) about industry demand under quantity competition (Novshek and Sonnenschein, 1982; Clarke, 1983; Vives, 1984; Gal-Or, 1985). Li (1985) bridges these two strands by distinguishing between firm-specific parameters (e.g., marginal costs) and common parameters (e.g., industry demand for a homogeneous good).

Information sharing has also been widely studied in accounting, where the "quality" of the information to be disclosed (e.g., the value of a cost reduction) plays a crucial role. Verrecchia (1983) introduces a disclosure cost—potentially arising from rivals' reactions—implying that non-disclosure forces the follower to infer whether the information was unfavorable or simply too costly to reveal. Similarly, Darrough (1993) compares the disclosure of firm-specific and common parameters in Cournot and Bertrand markets but allows for the possibility that firms have no information to disclose. Hughes and Pae (2015) analyze a setting where firms disclose information about the value of R&D-driven cost reductions, leading to knowledge spillovers that benefit rivals. However, in their model, the rival is always aware of the cost reduction. We combine elements of both approaches: As in Darrough (1993), a firm may lack information to disclose if it was not successful developing a new technology. Like in Hughes and Pae (2015), disclosure affects not only the rival's product-market strategy but also its standalone profitability.

[3] Milgrom and Roberts (1982) consider an incumbent that signals entry profitability through its pricing decision, though post-entry competition is in quantities. The only study considering price competition is Mailath (1989), where both duopolists signal through their price choice.

However, while in Hughes and Pae (2015) disclosure passively reduces the rival's cost through fixed knowledge spillovers, in our setting, it influences the rival's R&D decision.

Literature on the Disclosure of Patents and Innovation. A substantial body of theoretical work examines an innovator's incentive to patent a new technology or to keep it secret (Horstmann et al., 1985; Scotchmer and Green, 1990; De Fraja, 1993; Aoki and Spiegel, 2009; Jansen, 2011; Pease et al., 2024). In this context, patents function as a form of disclosure, as they require the publication of technical details. Competitors may benefit from access to this information, possibly eroding the innovator's advantage and discouraging patenting. In contrast, in our setting, firms exploit the statutory secrecy period of pending patent applications without jeopardizing eventual patent protection. Moreover, disclosure in our model does not reveal technical details but merely the existence of a new technology.

Another strand of research explores disclosure in settings where multiple intermediate R&D results are required for a final innovation. In such cases, firms may strategically disclose intermediate research results to influence a competitor's behavior in R&D competition (Baker and Mezzetti, 2005; Bar, 2006; Gill, 2008; Kim and Poggi, 2025). Akcigit and Liu (2016) examine the related question of a firm's incentive to disclose dead-end findings (i.e., terminal R&D failures) when multiple research paths exist. Jansen (2010) instead studies a firm's incentive to disclose its R&D investment cost, which affects their rival's R&D investment incentives. While we do not model direct R&D competition, the (non-)disclosure decision in our setting is partly motivated by its impact on the rival's R&D decision.

Many empirical studies of disclosure examine its effects by exploiting natural experiments, that is, they investigate the impact of exogenous changes in disclosure rates (e.g., Baruffaldi and Simeth, 2020; Lück et al., 2020; Hegde et al., 2023; Gross, 2023). Closest to our setting, Kim and Valentine (2021) find that mandatory disclosure of pending patent applications under the American Inventor's Protection Act affects firms' innovation incentives. The net effect depends on whether the benefits of receiving disclosures from others outweigh the costs of revealing one's own information.

In contrast, we examine a firm's individual disclosure decision in light of its impact on the rival's behavior. Moreover, by accounting for the nature of competition, we extend beyond existing studies of discretionary disclosure, which typically consider only the intensity of product market competition (Glaeser and Landsman, 2021; Rathee et al., 2025).

Press Releases as a Data Source. Press releases are an underutilized source of firm-level information. Aside from Ikeuchi (2017), we are not aware of other studies using press releases to analyze firm-level innovation.[4] Recent empirical work has instead focused on extracting information from earnings calls, annual reports, or data scraped from firms' websites (see **?** for a review). However, these sources are substantially larger than press releases and cover a much broader range of topics, making it harder to interpret them through the lens of our model. Our model is agnostic to the specific channel of innovation disclosure, and we acknowledge the existence of alternative channels, many of them unobservable, such as personal communication. Press releases offer the distinct advantage of being easily observable and they can be clearly linked to a specific topic.

3 Model

We consider an industry in which two firms compete in both the technology space and the product market. A technology leader L has access to new technology (e.g., a new production process or a new product design), whereas the follower F (initially) produces under a status-quo technology. The technologies are substitutes, and the new (or superior) technology is strictly better than the status-quo technology. The firms are aware of their respective roles; the leader's technology type, however, is known only to the leader. We refer to the leader with a superior technology as a "good" leader (indexed

[4] Press releases have been examined in other contexts, both as objects of study in their own right (Neuhierl et al., 2013; Ahern and Sosyura, 2014) and as proxies for broader firm disclosure (Burks et al., 2018; Bourveau et al., 2024).

by subscript G) and to the leader without a superior technology (producing under the status-quo technology) as a "bad" leader (indexed by subscript B).[5]

The follower can invest in R&D to develop her own version of the new technology. This version may differ from the leader's version in many dimensions, but it has the same cost-saving effect or consumer-demand effect as the leader's version.[6] The follower's R&D efforts are uncertain, and the outcome is observed (and available in the product market) only with a one-period delay. The extent to which the follower's R&D outcome is uncertain is partly determined by the leader's R&D outcome. We assume that leader and follower engage in technologically similar R&D projects and that their success probabilities are therefore correlated. This implies that successful R&D by the leader (exogenous in this model) increases the follower's success probability.[7] Likewise, the follower's beliefs that the leader is a good type increase her expectations that R&D is going to be successful (e.g., Austin, 1993; Krieger, 2021).

At the outset of the game, the leader can announce the existence of its new technology and thus influence the follower's decision to invest in R&D. We describe the details of the information environment and the leader's announcement below. The two firms compete in the product market space twice. We assume the leader with a superior technology has a patent application, and the announcement of a new technology is equivalent to announcing that the leader has applied for a patent. Following current legal practice in the United States and elsewhere, the leader's patent application is published (after 18 months) regardless of its examination status.[8] We assume that examination and publication of the application take place after stage-1 competition but before the follower

[5]We assume one-sided asymmetric information about the leader's type. The respective properties of the technologies (e.g., marginal costs if the technology is a cost-saving technology or consumer valuation if the technology is a new product design) are known to both firms.

[6]With this modeling assumption, we rule out "leap-frogging" (e.g., Fudenberg et al., 1983) where follow-up innovation is superior to existing (new technology). Note, however, that we do not assume the follower is an imitator, simply using the leader's technology in its own production process. The assumption that the follower's technology differs in many dimensions opens up the possibilities for alternative technologies with the same effect.

[7]An alternative assumption could involve potential technology spillovers. Such spillovers would be harder to reconcile with the setting of unobservable R&D outcomes, however.

[8]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 pursuing patent protection outside of the United States. See Johnson and Popp (2003), Popp et al. (2004), Aoki and Spiegel (2009), Koenen and Peitz (2012), or Graham and Hegde (2015).

Figure 1: Timeline of the Message-Innovation Game

	$t = 0:$	Leader G with patent application
	$t = 1:$	Leader's announcement
	$t = 2:$	Follower invests in R&D
Stage 1	$t = 3:$	Stage-1 competition
	$t = 4:$	Patent application is published and examined
	$t = 5:$	Leader and follower observe follower's R&D outcome
	$t = 6:$	License negotiations
Stage 2	$t = 7:$	Stage-2 competition

observes the outcome of her own R&D efforts and subsequent stage-2 competition. This means that, while stage-1 competition is under asymmetric information (driven by the follower's beliefs about the leader's type), stage-2 competition is under complete information.

Figure 1 summarizes the timeline of our model. In the following section, we provide more details and structure for the key ingredients of our model.

3.1 Disclosing an Application

We assume that the good technology leader type G with a new technology has applied for a patent, whereas the bad technology leader type B has not. In other words, the existence of a superior technology implies a patent application, and vice versa.

Assumption 1. *The technology leader has a patent application if and only if it is the good type.*

The good technology leader can credibly announce the existence of a patent application (and thus the existence of a new technology by Assumption 1) by sending a message $m = A$ or remain silent, $m = \varnothing$. Such an announcement can be in the form of a press release, a public statement, or a pending-patent mark on a product the firm sells. We assume for the moment that the technology leader can credibly disclose the existence of a technology without revealing any technical details of that technology. This relates to the notion of revealing the *What?* without the *How?* as discussed in Burstein (2012). As a consequence, only a technology leader with a patent application can announce its existence, implying that the bad leader type is passive (with $m = \varnothing$).[9]

Assumption 2. *The good technology leader (as the only patent applicant) can credibly announce her technology. Her action set is* $M_G = \{A, \varnothing\}$*. The bad leader (without a patent application) is a passive player with* $M_B = \{\varnothing\}$*.*

We denote the leader's (mixed) strategy of announcing its technology (or patent application) in $t = 1$ by $\mu_G = \Pr(m = A|G)$ for the good leader an $\mu_B = \Pr(m = A|B) = 0$ for the (passive) bad leader. This means, $\mu \in \{0, 1\}$ in pure strategies and $\mu \in [0, 1]$ in mixed strategies. We denote the leader's strategy profile by $\bar{\mu} = (\mu_G, \mu_B)$. Upon observing the announcement (or lack thereof), the follower can update beliefs $\hat{\theta}_1 \equiv \hat{\theta}(m|\bar{\mu})$ about the leader's type for stage-1 competition. Because only the good leader type can announce an application, $\hat{\theta}(A|\bar{\mu}) = 1$ for all $\bar{\mu} = (\mu_G, 0)$. Without an announcement, the follower updates their beliefs following Bayes' rule:

$$\hat{\theta}(\varnothing|\bar{\mu}) = \frac{\Pr(m = \varnothing|G)\Pr(i = G)}{\Pr(m = \varnothing|G)\Pr(i = G) + \Pr(m = \varnothing|B)\Pr(i = B)}$$

where $\Pr(i = G) = \theta$ is the follower's prior belief that the leader is the good type, and $\Pr(i = B) = 1 - \Pr(i = G)$.[10] Moreover, $\Pr(m = \varnothing|G) = 1 - \mu_G$ and $\Pr(m_B = \varnothing|B) = 1$ are the probabilities that the good type and the bad type do not announce the application. Upon observing m, the follower's posterior is:

$$\hat{\theta}_1 \equiv \hat{\theta}(m|\bar{\mu}) = \begin{cases} \hat{\theta}(A|\bar{\mu}) = 1 & \text{if } m = A, \text{ for all } \bar{\mu} = (\mu_G, 0) \\ \hat{\theta}(\varnothing|\bar{\mu}) = \dfrac{\theta(1-\mu)}{1-\theta\mu} & \text{if } m = \varnothing \end{cases} \tag{1}$$

[9] Our model misses one arm (the bad type taking action) in a standard two-player, two-type signaling game. Deterrence from penalties for false representation under the false marking provisions in 35 U.S.C. §292 or reputational concerns (e.g., Koenen and Peitz, 2015) are possible explanations for a non-patent applicant's inability (or lack of willingness) to announce.

[10] The prior belief here is equivalent to the ex-ante, unconditional success probability of R&D. This means that it is also the ex-ante probability that the leader is of the good type.

Stage-1 competition (in $t = 3$) is under asymmetric information with $\hat{\theta}(m|\bar{\mu})$. The respective profits (characterized below) are equilibrium profits from a Bayesian Nash equilibrium in this subgame. Note that, unlike stage-1 competition, stage-2 competition (in $t = 6$) is under complete information. First, the leader's technology is fully revealed by the publication of its patent application in $t = 4$ with the follower's beliefs:

$$\hat{\theta}_2 = \begin{cases} 1 & \text{if leader is } i = G \\ 0 & \text{if leader is } i = B; \end{cases} \tag{2}$$

and second, we assume that the outcome of the follower's R&D is observed by both firms in $t = 5$.[11] The respective profits (characterized below) are equilibrium profits from a Nash equilibrium under complete information.

3.2 Technology Spillovers and Follower's R&D

Following the leader's announcement (or lack thereof) in $t = 1$, the follower in $t = 2$ invests in R&D at constant cost K. This R&D investment is successful (and the follower has access to her own version of the new technology) with probability $\tilde{\theta} = \tilde{\theta}(\hat{\theta}_1)$. From an ex-ante point of view, we assume the leader's and follower's success probabilities are identical (in other words, the follower is not lagging because of lower skill or expertise). Ex ante (i.e., without any updates on the type of the leader), given that the leader is expected to have the new technology with prior probability θ, the follower will expect to obtain her own version of the new technology (conditional on R&D investment) with the same probability θ. Following Krieger (2021), we assume that R&D outcomes are (positively) correlated. This means the follower can update her beliefs about her own

[11] Absent discounting, this assumption is without loss of generality. If the follower's R&D outcome were not immediately observable by the leader, the only uncertainty in stage 2 would be about whether the follower infringes the leader's patent or not. There would be no uncertainty about whether the follower produces the high or the low quality. She will have access to the high quality via the now-public patent document and no incentive not to use this information. The remaining uncertainty about the source of the follower's high quality could be solved, e.g., by the follower's own patent application being published in an additional stage 3, or the leader spending a certain "investigative" effort to determine the source of the follower's knowledge (similar to the market monitoring effort in Crampes and Langinier (2002), or via the discovery proceedings following the filing of a patent infringement lawsuit). This way, the leader would receive her licensing fees for stage 2 in the form of infringement damages payments in stage 3.

success probability given her beliefs about the leader's success. Let $\tau \in [0,1]$ capture the degree of the technology spillover. For the follower's success probability, given uncertainty about the leader's type (i.e., success), we assume the following structural form:

$$\tilde{\theta}(\hat{\theta}_1) = \theta + \tau\left[\hat{\theta}_1 - \theta\right] = (1-\tau)\,\theta + \tau\hat{\theta}_1. \tag{3}$$

The follower's expectation that it will successfully develop her own version of the technology, as a function of her own beliefs about the leader's type, is a weighted average of the follower's prior and posterior beliefs about the leader's type (and R&D success). The follower's expectations that her R&D is successful is strictly increasing in her beliefs about the leader's type for all $\tau > 0$.[12]

It is helpful to characterize the follower's success probability under complete information. We denote these success probabilities by $\tilde{\theta}_G$ if the leader is of the good type and $\tilde{\theta}_B$ if the leader is of the bad type. Note that these are equivalent to the leader's own expectations about the follower's success (and equivalent to the follower's expectations about its own success probability when knowing the leader's type under complete information with $\hat{\theta}_1 = 1$ if the type is good and $\hat{\theta}_1 = 0$ if the type is bad):

$$\left.\begin{array}{lllllll} \tilde{\theta}_B & = & \theta + \tau\,(0-\theta) & = & (1-\tau)\,\theta & & \\ \tilde{\theta}_G & = & \theta + \tau\,(1-\theta) & = & (1-\tau)\,\theta + \tau & = & \tilde{\theta}_B + \tau \end{array}\right\} \tag{4}$$

The follower's expectations (under incomplete information) are then equal to

$$\tilde{\theta}(\hat{\theta}_1) = \hat{\theta}_1\tilde{\theta}_G + \left(1-\hat{\theta}_1\right)\,\tilde{\theta}_B$$

which yields expression (3) above.

[12]Note that in a separating equilibrium, in which the good leader announces $m = A$ (and the passive bad leader does not announce), the follower's R&D is no longer uncertain.

3.3 Product Market

We take a reduced-form characterization of product market competition between two firms. Our approach nests, in a tractable way, models of competition in strategic substitutes as well as in strategic complements and both cost-reducing as well as demand-increasing innovation.[13] For the notation of our reduced-form product-market payoffs, let i and j be two firms that are in direct competition. Firms can be of either a good type (with new technology) or a bad type (without a new technology). Moreover, let π_{ij} denote a firm i's profits (facing firm j) under complete information (when both firms know each other's types). Our reduced-form characterization of the product-market profits has the following properties:

Property 1. *With the new technology (good type), firm i obtains a competitive advantage so that $\pi_{GB} > \pi_{GG}$, $\pi_{BB} > \pi_{BG}$, and $\pi_{GG} > \pi_{BB}$.*

We normalize firm i's complete information profits when it operates under the status-quo technology and faces a competitor with a good technology to zero, $\pi_{BG} = 0$. The first property then implies the following ordering of complete-information profits:

$$\pi_{GB} > \pi_{GG} > \pi_{BB} > 0 = \pi_{BG}. \tag{5}$$

To further simplify the analysis, we additionally introduce the following property, which implies that both firms always find it mutually profitable to license.

Property 2. *Firms jointly benefit from knowledge transfer: $2\pi_{GG} > \pi_{GB} + \pi_{BG}$*

The last property generalizes implications from simple models of price and quantity competition. To see this, consider a simple model of competition à la Bertrand in which prices are strategic complements. Knowledge of firm i's good type (e.g., lower costs) makes firm j a more aggressive competitor, thus reducing firm i's Bayesian equilibrium profits. Conversely, knowledge of firm i's bad type (e.g., higher costs) makes firm j a

[13]The key properties of the reduced-form model can be obtained with simple product-market competition models such as the widely used one by Singh and Vives (1984). As such, our model is an extended version of the model in Angenendt et al. (2019) that assumed Bertrand competition.

less aggressive competitor, thus increasing firm i's profits.[14] The reverse patterns apply when firms compete in strategic substitutes, as for instance, in a linear-demand Cournot model.

Property 3. *In Bayesian Nash equilibrium, when firm j does not know firm i's type, firm i's profits decrease in firm j's beliefs that i has access to the new technology when the firms compete in strategic complements. Firm i's profits increase in firm j's beliefs when the firms compete in strategic substitutes.*

For our analysis below and following our Property 3, it is useful to characterize the leader's (firm i's) profits as a function of the follower's (firm j's) beliefs $\hat{\theta}_1$. These profits are Bayesian Nash equilibrium payoffs (under incomplete information) in stage 1 and Nash equilibrium payoffs (under complete information) in stage 2.[15] We use $\sigma \in (\underline{\sigma}, \overline{\sigma})$, with $\underline{\sigma} \in (-1, 0)$ and $\overline{\sigma} \in (0, 1)$, to capture the effect of the follower's beliefs on the leader's equilibrium profits. The firms compete in strategic complements if $\sigma > 0$ and strategic substitutes if $\sigma < 0$. In the case of $\sigma = 0$, information about the other firm's technology type does not affect a firm's optimal product-market strategy. The (informed) leader's profits $\tilde{\pi}_i$ (with $i = B, G$) in reduced form are then:[16]

$$\tilde{\pi}_i(\hat{\theta}_1) = \begin{cases} \tilde{\pi}_B & = & \big(1 - \sigma\hat{\theta}_1\big)\pi_{BB} \\ \tilde{\pi}_G & = & \big(1 + \sigma\big(1 - \hat{\theta}_1\big)\big)\pi_{GB} & = & \big(1 - \sigma\hat{\theta}_1 + \sigma\big)\pi_{GB}. \end{cases} \tag{6}$$

This expression is decreasing in posterior beliefs $\hat{\theta}_1$ for both types. One key implication is that, under strategic complements, the bad type leader prefers complete information (with $\hat{\theta}_1 = 0$) to uncertainty at stage 1 (with $\hat{\theta}_1 > 0$). In contrast, the good type with the technology prefers uncertainty (with $\hat{\theta} < 1$ to complete information (with $\hat{\theta}_1 = 1$). Under strategic substitutes, these preferences by the leader are reversed.

[14] See Saloner (1987) and Ordover and Saloner (1989), and Tirole (1988) or Vives (1999) for textbook treatments.

[15] Stage-2 payoffs can be also be characterized as equilibrium payoffs from a degenerate Bayesian Nash equilibrium with polar beliefs $\hat{\theta} \in \{0, 1\}$.

[16] These profits under incomplete information reduce to the profits under complete information with $\tilde{\pi}_B(0) = \pi_{BB}$ and $\tilde{\pi}_G(1) = \pi_{GG}$.

3.4 Intellectual Property

Patents are generally not ironclad legal rights, but whether a patent is valid (and the ensuing intellectual property right enforceable) is subject to dispute (e.g., Lemley and Shapiro, 2005; Farrell and Shapiro, 2008). We incorporate this feature of intellectual property rights into our model and assume the patent is granted (or, if it is granted, upheld in court) with probability $\gamma \in [0,1]$. We allow for the follower's new version to be sufficiently different so that, even if the leader has a valid patent, the follower's version is not necessarily infringing on the leader's patent. We assume that, conditional on the leader's patent being valid and the follower's R&D success, the follower's technology infringes on the leader's patent with probability $\eta \in [0,1]$. For notational ease, we will write $\beta \equiv (1-\eta)\,\gamma$.

If the follower does not develop her own version of the technology or infringes on the leader's patent, she can take out a license at a fixed fee λ. A follower who believes the leader is of the good type (with a patent application) and invests in R&D at $t = 2$ expects to pay the license fee with probability

$$\tilde{\theta}_G \gamma \eta + \left(1 - \tilde{\theta}_G\right)\gamma \quad = \quad \gamma - \beta \tilde{\theta}_G;$$

a follower who does not invest expects to pay the license fee with probability γ.

4 Equilibrium of the Message-Innovation Game

In the sequel, we derive the perfect Bayesian equilibria of the message-innovation game described above.

Definition 1. *The perfect Bayesian equilibrium of the message-innovation game is a triple* $\left\{\bar{\mu}, \bar{\rho}, \hat{\theta}_1\right\}$ *with* $\bar{\mu} = (\mu_G, 0)$ *and* $\bar{\rho} = \left(\rho_A, \rho_\varnothing\right)$.

We first characterize the outcome of license negotiations in $t = 6$ given the realization of the patent examination process in $t = 4$ and the follower's R&D in $t = 5$. We then derive conditions under which the follower invests in R&D in $t = 2$, and the leader announces its technology in $t = 1$.

4.1 License Negotiations

At the license negotiations stage $t = 6$, the leader's patent application has been examined, and the patent granted. Moreover, the follower has not invested in R&D, the investment failed, or the investment was successful, but her version of the new technology is infringing on the leader's patent. In these three scenarios, the follower can take out a license and produce under the new technology in stage-2 competition ($t = 7$). Alternatively, the follower produces under the status-quo technology.[17] For the bargaining outcome we assume symmetric Nash bargaining, and the firms split the bargaining surplus equally.

Lemma 1. *The license fee as an outcome from a symmetric Nash bargaining solution is* $\lambda = \frac{\pi_{GB}}{2}$.

4.2 Follower's R&D Decision

There are two reasons for the follower to invest in R&D. First, if she believes the leader is of the bad type and operates under the status-quo technology (so that $\hat{\theta}_1 = 0$ and $\tilde{\theta}(\hat{\theta}_1) = \tilde{\theta}_B$), R&D investment can provide for a competitive advantage (albeit with a delay). We denote the profit effect of this competitive advantage in stage-2 competition by $\psi_{F|B}$. It is equal to:

$$\psi_{F|B} \equiv \pi_{GB} - \pi_{BB}; \tag{7}$$

and the expected profit effect of the competitive advantage is $\tilde{\theta}_B \psi_{F|B}$. Second, if the follower believes the leader is of the good type and operates under a new technology (so that $\hat{\theta}_1 = 1$ and $\tilde{\theta}(\hat{\theta}_1) = \tilde{\theta}_G$), then she invests in R&D to avoid having to pay the license fee λ. We denote the license-fee savings as a result of successful R&D investment by $\psi_{F|G}$.

[17] We assume the leader's threat to obtain injunctive relief is credible. See the discussion, for instance, in Denicolò et al. (2008).

Let $\beta = (1-\eta)\,\gamma$, then the license-fee savings are:[18]

$$\psi_{F|G} \equiv \beta\lambda = \frac{\beta\pi_{GB}}{2}. \tag{8}$$

For the complete characterization of the follower's payoffs, we use $r = 1$ if the follower has invested and $r = 0$ if otherwise. Given the leader's decision to announce $m \in \{A, \varnothing\}$ and the follower's R&D investment $r \in \{0, 1\}$, the follower's expected net payoffs $\pi_F(m, r)$ in $t = 2$ are equal to:

$$\begin{aligned} \pi_F(m,r) \;\; &= \;\; \hat{\theta}(m|\bar{\mu})\Big[r\big[\pi_{GG} - \gamma\big(\tilde{\theta}_G\eta + \big(1-\tilde{\theta}_G\big)\big)\lambda\big] + (1-r)\,\big[\pi_{GG} - \gamma\lambda\big]\Big] + \\ & \big(1-\hat{\theta}(m|\bar{\mu})\big)\Big[r\big[\tilde{\theta}_B\pi_{GB} + \big(1-\tilde{\theta}_B\big)\,\pi_{BB}\big] + (1-r)\,\pi_{BB}\Big] - rK. \end{aligned} \tag{9}$$

We can simplify this expression to read:

$$\pi_F(m,r) \;\; = \;\; \hat{\theta}(m|\bar{\mu})\big[\pi_{GG} - \gamma\lambda + r\tilde{\theta}_G\psi_{F|G}\big] + \big(1-\hat{\theta}(m|\bar{\mu})\big)\big[\pi_{BB} + r\tilde{\theta}_B\psi_{F|B}\big] - rK. \tag{10}$$

The follower's expected net benefits from R&D, given the leader's decision m and the follower's beliefs $\hat{\theta}(m|\bar{\mu})$, are defined as the difference between the follower's expected net payoffs when she invests in R&D ($r = 1$) relative to when she does not invest in R&D ($r = 0$),

$$R(\hat{\theta}(m|\mu)) \equiv \pi_F(m,1) - \pi_F(m,0).$$

Lemma 2. *The follower's expected net benefits from R&D investment, given m and thus $\hat{\theta}_1$, are*

$$R(\hat{\theta}) = \hat{\theta}_1\tilde{\theta}_G\psi_{F|G} + \big(1-\hat{\theta}_1\big)\tilde{\theta}_B\psi_{F|B} - K. \tag{11}$$

The follower invests if $R(\hat{\theta}_1) \geq 0$ and does not invest otherwise.

[18]If the follower successfully invests in R&D, she pays the license fee with probability $\gamma\eta$. If she does not invest, she pays the license fee with probability γ. The difference in expected license fees is $-(1-\eta)\,\gamma\lambda$; the negative thereof is equal to the savings.

These expected net benefits are the weighted average of what the follower expects to save in terms of license fees ($\psi_{F|G}$, when the leader is the good type) and what she expects to gain in the product market ($\psi_{F|B}$, when the leader is of the bad type), with the weights the respective posterior beliefs about the leader's type.

A necessary condition for the leader's announcement to have a deterring effect on the follower's investment decision is $R(\hat{\theta}(\varnothing|\bar{\mu})) > R(\hat{\theta}(A|\bar{\mu})) = R(1)$. It requires that the follower's net benefits after announcing $m = A$ are lower than without announcing. If the necessary condition is not satisfied, then announcing does not deter (as no announcing would render the investment by the follower even less likely); in fact, the announcement may *trigger* the follower's R&D investment. The following Lemma summarizes the effect of the leader's announcement m on the follower's R&D decision. It characterizes three different scenarios: an announcement by the leader can deter or trigger R&D investment by the follower. Moreover, the announcement may be ineffective as the follower will either always invest or never invest regardless of the leader's decision.

Lemma 3 (Announcements as R&D Deterrence)**.**

1. *The leader's announcement* $m = A$ *deters the follower's R&D investment if* $R(\hat{\theta}(\varnothing|\bar{\mu}) \geq 0 > R(\hat{\theta}(A|\bar{\mu})) = R(1)$ *or*
$$\frac{K - \left(1 - \hat{\theta}(\varnothing|\bar{\mu})\right)\tilde{\theta}_B \psi_{F|B}}{\hat{\theta}(\varnothing|\bar{\mu})} \leq \tilde{\theta}_G \psi_{F|G} < K.$$

2. *The leader's announcement* $m = A$ *triggers the follower's R&D investment if* $R(\hat{\theta}(\varnothing|\bar{\mu})) < 0 \leq R(1)$ *or*
$$\frac{K - \left(1 - \hat{\theta}(\varnothing|\bar{\mu})\right)\tilde{\theta}_B \psi_{F|B}}{\hat{\theta}(\varnothing|\bar{\mu})} > \tilde{\theta}_G \psi_{F|G} \geq K.$$

3. *The leader's announcement* $m = A$ *is ineffective if either* $\min\left\{R(1), R(\hat{\theta}(\varnothing|\bar{\mu}))\right\} \geq 0$ *(when the follower always invests, regardless of* m*) or* $\max\left\{R(1), R(\hat{\theta}(\varnothing|\bar{\mu}))\right\} < 0$ *(when the follower never invests, regardless of* m*).*

We can more generally state that the leader's announcement weakens the follower's R&D incentives if $R(\hat{\theta}(\varnothing|\bar{\mu})) > R(1)$ and strengthens it otherwise. For our equilibrium analysis below, the property of the follower's net benefits of R&D, as summarized in the following lemma, will prove to be useful.

Lemma 4. *The follower's net benefits from R&D decrease in the follower's beliefs $\hat{\theta}$ about the leader's type if and only if*

$$(1-\tau)\,\theta\left[\psi_{F|G}-\psi_{F|B}\right]+\tau\psi_{F|G}<0. \tag{12}$$

A necessary condition for condition (12) to hold is

$$\psi_{F|G}=\frac{\beta\pi_{GB}}{2}<\pi_{GB}-\pi_{BB}=\psi_{F|B}. \tag{13}$$

It requires that the competition effect from R&D be stronger than the license-savings effect. We can expect to see this more often when the leader's application is expected to be weak (grant probability γ is low) or broad (infringement probability η is large) so that the follower's R&D is more likely to infringe. In the former case, the follower expects to pay license fees with a lower probability but also anticipates the leader's technology to be free. In the latter case, the follower expects to pay the license fee with a higher probability, reducing the license fee savings.

4.3 Leader's Announcement in Equilibrium

For the full characterization of the equilibria in the message-innovation game, we need to spell out only the good type's strategy. Under Assumptions 1 and 2, the bad type is a passive player with $m=\varnothing$ and $\mu=0$. We distinguish two scenarios. In Scenario 1, the leader's announcement weakens the follower's R&D incentives (condition 12 holds); in Scenario 2, the announcement strengthens the R&D incentives (condition 12 is violated).

4.3.1 Scenario 1: Announcement Weakens the Follower's R&D Incentives

In a separating equilibrium, the good leader announces, $m=A$, whereas, in a pooling equilibrium, the good leader does not announce, $m=\varnothing$. In mixed strategies, the good leader announces with probability μ_G and remains silent with probability $1-\mu_G$.

The leader, when deciding whether to announce, trades off the payoff consequences in stage-1 competition ($\tilde{\pi}_G(\hat{\theta}(A|\bar{\mu}))$ and $\tilde{\pi}_G(\hat{\theta}(\varnothing|\bar{\mu}))$) against the payoff consequences in stage-2 competition. As discussed in the context of the expressions for $\tilde{\pi}_G$ in equation (6) above, the good leader's stage-1 competition profits are higher after an announcement if the firms compete in strategic substitutes (and $\sigma < 0$); conversely, the profits are lower after an announcement if the firms compete in strategic complements (and $\sigma > 0$).

For Propositions 1 and 2, we first consider the case where the leader's announcement *deters* the follower's R&D investment (when $R(\theta) \geq 0 > R(1)$).

Proposition 1. *Let $R(\theta) \geq 0 > R(1)$. The message-innovation game has the following unique perfect Bayesian equilibrium in pure strategies. The follower invests in R&D if $m = \varnothing$ and does not invest in R&D if $m = A$. Moreover:*

1. *the leader announces and $m = A$ ("separating equilibrium") if*

$$\frac{2\sigma}{(1-\tau)\,\theta+\tau} \leq \beta; \tag{14}$$

2. *the leader does not announce and $m = \varnothing$ ("pooling equilibrium") if*

$$\frac{2\sigma\,(1-\theta)}{(1-\tau)\,\theta+\tau} \geq \beta. \tag{15}$$

The proposition does not characterize an equilibrium for the entire parameter space. In fact, for parameter values such that

$$\frac{2\sigma\,(1-\theta)}{(1-\tau)\,\theta+\tau} < \beta < \frac{2\sigma}{(1-\tau)\,\theta+\tau}$$

neither condition (14) nor condition (15) is satisfied. The following proposition summarizes the ensuing equilibrium in mixed strategies in which the leader announces the technology with a probability μ_G^*.

Proposition 2. *Let $R(\theta) \geq 0 > R(1)$. The message-innovation game has the following perfect Bayesian equilibrium in mixed strategies. The follower invests in R&D if $m = \varnothing$*

and does not invest if $m = A$. Moreover, the leader announces a pending patent with probability μ_G^*:

$$\mu_G^* = \frac{1}{\theta} - \frac{1-\theta}{\theta}\frac{2\sigma}{[(1-\tau)\theta+\tau]\beta}. \tag{16}$$

Propositions 1 and 2 assume that the leader's announcement has a deterring effect on the follower's investment. We continue to assume that condition (12) holds true (i.e., announcement weakens the follower's R&D incentives), but either $R(\theta) > R(1) \geq 0$ so that the follower invests or $0 > R(\theta) > R(1)$ so that the follower does not invest—regardless of the leader's message. In either case, the leader announces the technology when the firms compete in strategic substitutes ($\sigma < 0$) and does not announce when the firms compete in strategic complements ($\sigma > 0$).

Proposition 3. *Let* $\min\{R(\theta), R(1)\} \geq 0$*, so that the follower always invests in R&D, or* $0 > \max\{R(\theta), R(1)\}$*, so that the follower never invests in R&D, regardless of the leader's message m. In the unique perfect Bayesian equilibrium of the message-innovation game, the leader announces and $m = A$ ("separating equilibrium") if $\sigma \leq 0$; the leader does not announce and $m = \varnothing$ ("pooling equilibrium") if $\sigma \geq 0$.*

Proposition 3 mirrors the results in Gal-Or (1986) that shows that disclosure is optimal in Cournot competition (strategic substitutes), whereas is optimal in Bertrand competition (strategic complements). The results further hold for both Scenario 1 and Scenario 2 discussed next.

4.3.2 Scenario 2: Announcement Strengthens the Follower's R&D Incentives

For a full picture of the model, we now consider the case where the leader's announcement strengthens the follower's investment incentives (when condition (12) is not satisfied). The results in Proposition 3 apply to the case under this scenario where the follower either always invests in R&D or never invests in R&D (and the leader's announcement has no effect on the investment decision). The results discussed below, therefore, apply only to the case in which the leader's announcement, in fact, *triggers* R&D investment by the follower, that means, when $R(1) \geq 0 > R(\theta)$ and $R(\theta')$ increasing in θ'. Such a scenario arises when there are strong technology spillover effects, and firms learn from their competitors' R&D success (Austin, 1993; Krieger, 2021). Proposition 4 summarizes the results.

Proposition 4. *Let $R(1) \geq 0 > R(\theta)$. The message-innovation game has the following perfect Bayesian equilibrium in pure strategies. The follower invests in R&D if $m = A$ and does not invest in R&D if $m = \varnothing$. Moreover:*

1. *the leader announces and $m = A$ ("separating equilibrium") if*

$$-\frac{2\sigma}{(1-\tau)\theta+\tau} \geq \beta; \tag{17}$$

2. *the leader does not announce and $m = \varnothing$ ("pooling equilibrium") if*

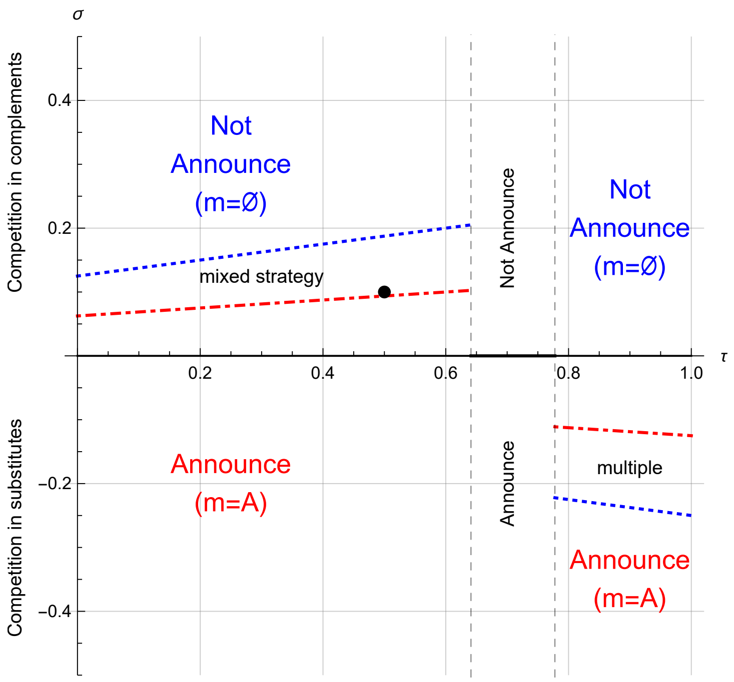
$$-\frac{2\sigma(1-\theta)}{(1-\tau)\theta+\tau} \leq \beta. \tag{18}$$

Note that the equilibrium is not unique for parameter values such that both of these conditions are satisfied. A necessary condition for multiple equilibria is $\sigma < 0$. When both equilibria exist, we show in the proof that the leader prefers the pooling equilibrium.

5 Comparative Statics and Predictions

Our model extends earlier theoretical results in Gal-Or (1986), Darrough (1993), or Hughes and Pae (2015) by introducing the effect of an announcement of successful innovation (by way of a patent application) on a competitor's R&D incentives. In our model, when deciding to announce the patent application or keep it secret (until it is published by the patent office), the leader trades off the short-term value of secrecy in stage-1 competition and the long-term value of deterring innovation. In Figure 2, we plot the leader's equilibrium announcement decisions in the technology-competition (that is, τ-σ) space. This figure helps distinguish three main situations that we discuss in turn.

Figure 2: Equilibrium Outcomes in Technology-Competition Space



Notes: The figure plots the leader's equilibrium announcement decisions in the technology-competition (τ-σ) space. Negative values of σ indicate environments with competition in strategic substitutes; positive values of σ environments with competition in strategic complements. For low values of τ, the outcomes are by Proposition 1 (for pure strategies) and 2 (for mixed strategies); for intermediate values of τ, the outcomes are by Proposition 3; for high values of τ, the outcomes are by Proposition 4. Other parameters are $\theta = 1/2$, $\eta = 1/2$, $\gamma = 1/2$, $\pi_{GB} = 3$, $\pi_{GG} = 2$, $\pi_{BB} = 1$, and $K = 1/3$.

Without an effect of the announcement on the follower's R&D decision, the leader's decision is the same as in Gal-Or (1986). The value of secrecy is negative when competition is in strategic substitutes ($\sigma < 0$) and announcing, $m = A$, is optimal; the value of secrecy is positive when competition is in strategic complements ($\sigma > 0$) and concealing, $m = \varnothing$, is the leader's optimal decision. This situation occurs for intermediate values of τ (and the equilibrium is characterized in Proposition 3).

For lower values of τ, when the announcement deters the follower's R&D investment (and the equilibria are characterized in Propositions 1 and 2), the leader announces even when competition is in strategic complements for some $\sigma > 0$ (when in Gal-Or (1986) she would not announce). For these values of σ, the value of secrecy is not enough to offset the lost value of deterring R&D.

For higher values of τ, when the announcement encourages the follower's R&D investment (and the equilibria are characterized in Proposition 4), the leader will not disclose for some $\sigma < 0$ (when in Gal-Or (1986) she would announce). In this case, triggering the follower's R&D by announcing is more costly than inducing fiercer competition by the follower (for $\sigma < 0$).

The results give rise to two main predictions. First, as we have illustrated in Figure 2, announcements of patent applications are more likely in industries with competition in strategic substitutes (negative values σ) and where the correlation of R&D success is limited (low values of τ). We summarize these two predictions as follows:

Prediction 1. *Announcements of pending patent applications are more likely when competition is characterized by strategic substitutes more than strategic complements (and σ is small).*

Prediction 2. *Announcements of pending patent applications are more likely when the success of R&D investments does not correlate much (and τ is small).*

The third prediction from our model builds on the additional effect of R&D deterrence on the leader's decision. The more learning about a competitor's success reveals about one's own R&D prospects, the more likely an announcement can *trigger* the follower's R&D investment. The positive association of strategic substitutability with announcements, therefore, weakens with higher values of τ; conversely, the negative association of strategic complementarity with announcements strengthens with higher values of τ. We summarize this in the following prediction:

Prediction 3. *The negative association of σ with the leader's announcement decision is stronger for higher values of τ.*

In the next section, we present empirical evidence for these predictions.

6 Empirical Evidence

6.1 Variable Construction

We test the predictions using industry-level data for the United States. Our outcome variable is the industry-level prevalence of firms' announcements of pending patents by way of press releases. For our two model parameters of interest, we construct measures for the nature of competition (as a proxy for σ) and firm's product-market proximity to its industry rivals (as a measure of R&D correlation).

6.1.1 Disclosure of Pending Patents

To obtain data on the disclosure of pending patents, we searched for press releases on NexisUni[19] using variations of the search terms "('patent application' OR 'patent applications') AND ('files' or 'filed')". We then restrict results to source types "press releases" or "newswires" that are published in the region "United States" between 2015 and 2021. This search procedure yielded approximately 30,000 results of which we downloaded the full text. We classified each downloaded document as to whether it indeed announced a pending patent application (rather than, for instance, a patent grant), and whether it was released by the patent applicant (rather than, for instance, an industry news source or trade association).

Our final sample comprises 1,797 announcements of pending patents in U.S. press releases. For the issuing companies of these press releases, we obtain the 6-digit NAICS industry code from Bureau van Dijk's Orbis database. In the analysis reported below, we construct an indicator variable that takes value 1 if at least one press release in our dataset was associated with this industry, and value 0 otherwise.[20]

6.1.2 The Nature of Competition

For our measure of the nature of competition as a proxy for the model parameter σ, we rely on an approach introduced to the corporate finance literature by Kedia (2006).[21] Following Bulow et al. (1985), the nature of competition in an industry is determined by

[19] See https://www.lexisnexis.com/en-us/professional/academic/nexis-uni.page.

[20] Using the number of observed press releases (and Poisson instead of Logistic regression) yields comparable results.

[21] Sundaram et al. (1996) are the first to attempt to empirically identify the mode of competition for a large number of industries, but their approach is not robust to external influences such as trends in the industry cost level. Methods developed in the empirical industrial organization literature (see Aguirregabiria (2021), chapter 4, for a textbook treatment) require firm-level data on sales quantities and prices over time. For a study of cross-industry variation in the nature of competition, these data would need to be collected for dozens if not hundreds of industries, making this approach prohibitively costly.

the sign of the cross-partial derivative of a firm's profit with respect to its competitors' strategic variable. Kedia (2006) proposes to approximate the value of this cross-derivative as follows (see equation (2) in Kedia (2006)): The total differential of marginal profit can be expressed as

$$d\left[\frac{\partial \pi_i}{\partial s_i}\right] = \beta_1 s_i \mathrm{d}s_i + \beta_2 \mathrm{d}s_i + \beta_3 s_i \mathrm{d}s_{-i} + \beta_4 \mathrm{d}s_{-i} \tag{19}$$

Marginal profit can be approximated as the quarterly change in a firm's net income ($\Delta\pi_i$) divided by the quarterly change in the firm's net sales (Δs_i); $\mathrm{d}s_{-i}$ is the change in the total output of all competitors, that means, all other firms in the same industry. Equation (19)) is then estimated by OLS, and the cross-partial derivative is approximated by the linear combination:

$$\hat{\beta}_3 \bar{s}_i + \hat{\beta}_4, \tag{20}$$

where $\bar{s}_i$ is the mean value of s_i during the sample period used in estimation.

We use quarterly data for publicly traded firms (obtained from Compustat) to obtain our industry-level measures for σ.[22] Because the approach by Kedia (2006) reliably identifies the sign, but not the magnitude, of σ, we generate a variable $\tilde{\sigma}_i$ at the firm level that takes a value of $\tilde{\sigma}_i = 1$ if the estimate in equation (20) is positive and a value of $\tilde{\sigma}_i = -1$ if the estimate is negative. We then approximate the value of σ in an industry by taking the average over all firms in that industry, $\hat{\sigma} = \mathrm{E}(\tilde{\sigma}_i)$. Following the approach taken in Chod and Lyandres (2011), we use data from five consecutive years to obtain the estimate in equation (20) for the last year of that time window (for instance, we use data from 2016–2020 to calculate the measure of competition for 2020).

We obtain a measure of competition for 310 6-digit NAICS industries that contain at least two publicly traded firms.[23] Of these industries, 151 industries are estimated

[22] Using the subset of publicly traded companies to estimate industry-level measures representing all firms is standard practice in the finance literature (Sundaram et al., 1996; Kedia, 2006; Chod and Lyandres, 2011; Frésard and Valta, 2016).

[23] Industries for which Compustat provides data for a single firm only are discarded since we cannot calculate a measure of firm interaction. For 22 industries, the estimated measure is not significantly different from zero; we discard these industries from our analysis.

Table 1: Summary Statistics

Variable	**Competition in ...**		
	Complements	**Substitutes**	**N/A**
Number of industries	151	159	22
Number of industries with announcements	45	56	8
Mean number of announcing firms	1.10	1.78	0.77
Mean "intensity of interaction" ($\lvert\sigma\rvert$):			
... in industries with announcements	0.28	−0.31	
... in industries without announcement	0.39	−0.31	

to exhibit competition in complements (where $\hat{\sigma} > 0$) and 159 industries competition in substitutes (where $\hat{\sigma} < 0$).

We summarize our competition measure in Table 1. Of all industries with strategic complements, 29.8% experience announcements; of all industries with strategic substitutes, 35.2% experience announcements. Moreover, industries with competition in strategic substitutes feature on average 1.78 announcing firms, compared to 1.10 announcing firms per industry with competition in strategic complements. Both sets of numbers are consistent with Prediction 1, stating that announcements of pending patent applications are more likely when competition is characterized by strategic substitutes.

6.1.3 Correlation of Firms' R&D

We proxy the value of τ as the industry average of the pairwise similarity between firms' "product market" descriptions in their annual 10-K filings to the SEC. We obtain this measure from data prepared by Hoberg and Phillips (2016) which have been widely used in finance and industrial organization research (e.g., Bustamante and Frésard, 2021; Antón et al., 2023). This similarity measure provides a reasonable proxy for technological correlation since firms with greater product market similarity are also more likely to face similar technological challenges and therefore learn from each other's R&D success.

6.1.4 Additional Variables

In our regression analyses, we additionally control for the industry-level share of (very) small firms with fewer than 5 employees which we obtained from 2019 establishment

Table 2: Empirical Evidence from Press Releases

	(1)	(2)	(3)
Competition $\hat{\sigma}$	-0.503*	-0.781**	-0.755**
	(0.289)	(0.311)	(0.327)
R&D correlation τ			-6.317***
			(2.401)
Share of firms <5 employees		1.843***	2.003***
		(0.660)	(0.691)
Observations	332	298	285
Log. lik.	-208.6	-188.2	-177.3

Notes: Logistic regression of an announcement dummy at the 6-digit NAICS level. Constant term included but not reported.

data from the U.S. Census Bureau. This control variable captures the relative importance of patent applications as a means of startup firms to attract outside financing such as venture capital.[24]

6.2 Results

We report the results from logistic regressions in Table 2. The dependent variable is a binary variable taking the value 1 if at least one press release announcing a pending patent application has been assigned to this industry, and value 0 otherwise.

In line with Prediction 1, we find a significant negative association between the occurrence of patent announcements and competition in strategic complements (positive values of $\hat{\sigma}$). The estimated relationship becomes more pronounced (and more precise) when we additionally control for the share of small firms in the industry. A positive coefficient on this variable confirms the work by Mohammadi and Khashabi (2021) who find that disclosure of patent applications helps startups attract outside funding. More (active) announcements of patent applications in industries with more small firms is in line with this finding. Our proxy for τ is also negatively associated with the occurrence of announcements, supporting our Prediction 2.

[24] Mohammadi and Khashabi (2021) show that forced public disclosure of pending patent applications increases the likelihood of startups receiving venture capital funding. Earlier work had already established that patent applications help early-stage firms to receive venture capital funding (Baum and Silverman, 2004; Haeussler et al., 2009; Cockburn and MacGarvie, 2009; Hottenrott et al., 2016).

7 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, the 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, the announcement—for instance in the form of a press release—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 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 also show that the applicant announces more often when competition is in substitutes or when the correlation of firms' R&D successes is small.

We produce evidence supporting core predictions using press releases on patent application filings by U.S. firms. In doing so, we provide evidence supporting the theoretical prediction going back to Gal-Or (1986) (and expanded by Darrough (1993)) that production cost disclosure depends on the mode of competition in an industry.[25] Using patent applications as one relatively easily observable signal of the production cost level, we adapt the model and qualify the predictions for this special context.

[25] Sundaram et al. (1996) study how the mode of competition moderates the effect of R&D announcements on firms' stock prices. In doing so, they treat the occurrence of R&D announcements as exogenous. We show instead that such announcements are likely driven by the mode of competition itself.

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A Appendix

A.1 Formal Proofs of Theoretical Results

Proof of Lemma 1

The symmetric Nash bargaining solution implies an equal split of the bargaining surplus (Muthoo, 1999:p. 15). This surplus is $2\pi_{GG} - (\pi_{GB} + \pi_{BG}) = 2\pi_{GG} - \pi_{GB}$ and positive by Property 2. The leader's total payoffs are then equal to $\pi_{GB} + \frac{2\pi_{GG}-\pi_{GB}}{2} = \pi_{GG} + \frac{\pi_{GB}}{2}$, implying a license fee of $\lambda = \frac{\pi_{GB}}{2}$.

Proof of Lemma 3

1. Without an announcement (so that $R(\hat{\theta}(\varnothing|\bar{\mu})) \geq 0$) the follower invests; the announcement (so that $R(1) < 0$) renders the follower's net benefits from R&D negative, and the follower does not longer invest.

2. Without an announcement (so that $R(\hat{\theta}(\varnothing|\bar{\mu})) < 0$) the follower does not invest; the announcement (so that $R(1) \geq 0$) renders the follower's net benefits from R&D positive, and the follower invests.

3. If $\min\{R(1), R(\hat{\theta}(\varnothing|\bar{\mu}))\} \geq 0$, then then follower's net benefits are nonnegative regardless of m; if $\max\{R(1), R(\hat{\theta}(\varnothing|\mu))\} < 0$, then the follower's net benefits are negative regardless of m.

Proof of Lemma 4

Net benefits $R(\hat{\theta}_1)$ are increasing in $\hat{\theta}_1$ if

$$\frac{dR(\hat{\theta}_1)}{d\hat{\theta}_1} = \rho_G \psi_{F|G} - \rho_B \psi_{F|B} < 0.$$

Recall that $\rho_G = \rho_B + \tau = (1-\tau)\theta + \tau$. The above condition can be rewritten to read conditon (12).

Proof of Proposition 1

The follower's equilibrium strategies follow from the assumption that $R(\theta) \geq 0 > R(1)$. For the leader's strategy, first consider a separating equilibrium, $\mu_G = 1$. The leader's payoffs when it announces (and the follower does not innovate) are

$$\tilde{\Pi}_G(\hat{\theta}(A|(1,0))) = \pi_{GB} + \pi_{GG} + \gamma\lambda.$$

If (off equilibrium) the leader does not announce (and the follower innovates because her beliefs are $\hat{\theta}(\varnothing|(1,0)) = 0$), then her payoffs are:

$$\tilde{\Pi}_G(\hat{\theta}(\varnothing|(1,0))) = (1+\sigma)\,\pi_{GB} + \pi_{GG} + \gamma\lambda - \rho_G\psi_{F|G}$$

with $\gamma\lambda - \rho_G\psi_{F|G} \geq 0$. A separating equilibrium thus exists if $\tilde{\Pi}_G(\hat{\theta}(A|(1,0))) \geq \tilde{\Pi}_G(\hat{\theta}(\varnothing|(1,0)))$. Rearranging this condition and using the expressions for ρ_G and $\psi_{F|G}$ yields condition (14) in the Proposition.

Now, consider a pooling equilibrium, where the leader does not announce in equilibrium, $\mu = 0$. On the equilibrium path (observing $m = \varnothing$ and $\hat{\theta}(\varnothing|(0,0)) = \theta$), the follower invests in R&D. The leader's equilibrium payoffs are:

$$\tilde{\Pi}_G(\hat{\theta}(\varnothing|(0,0))) = (1+\sigma(1-\theta))\,\pi_{GB} + \pi_{GG} + \gamma\lambda - \rho_G\psi_{F|G}$$

If (off equilibrium), the leader announces, $m = A$, then $\hat{\theta}(A|0) = 1$ and the follower does not invest in R&D. The leader's off-equilibrium payoffs are:

$$\tilde{\Pi}_G(\hat{\theta}(A|(0,0))) = \pi_{GB} + \pi_{GG} + \gamma\lambda$$

A pooling equilibrium exists $\tilde{\Pi}_G(\hat{\theta}(\varnothing|(0,0))) \geq \tilde{\Pi}_G(\hat{\theta}(A|(0,0)))$. Rearranging this condition and using the expressions for ρ_G and $\psi_{F|G}$ yields condition (15) in the Proposition. Because $1-\theta \leq 1$, there is no γ such that both conditions (14) and (15) are satisfied.

Proof of Proposition 2

First, note that $R(\hat{\theta}(\varnothing|\bar{\mu})) \geq R(\theta)$ for all $\bar{\mu} = (\mu_G, 0)$, so that the deterrence condition holds for all $\bar{\mu}$. In other words, if the leader announces, the follower invests if and only if the (good) leader does not announce (for any given strategy μ_G). The (good) leader is willing to announce with probability μ_G if her payoffs from $m = A$,

$$\tilde{\Pi}_G(\hat{\theta}(A|\bar{\mu})) = \tilde{\pi}_G(\hat{\theta}(A|\bar{\mu})) + \pi_{GG} + \gamma\lambda = \pi_{GB} + \pi_{GG} + \gamma\lambda = \tilde{\Pi}_G(1) \tag{21}$$

are equal to her payoffs from $m = \varnothing$ (given $\bar{\mu}$),

$$\tilde{\Pi}_G(\hat{\theta}(\varnothing|\bar{\mu})) = \tilde{\pi}_G(\hat{\theta}(\varnothing|\bar{\mu})) + \pi_{GG} + \gamma\lambda - \rho_G\psi_{F|G}. \tag{22}$$

The equilibrium mixed strategy profile $\bar{\mu}^* = (\mu_G^*, 0)$ is then such that $\tilde{\Pi}_G(1) = \tilde{\Pi}_G(\hat{\theta}(\varnothing|\bar{\mu}^*))$. After some rearranging, we obtain the expression in (16) in the Proposition.

Proof of Proposition 3

For either $\min\{R(\theta), R(1)\} \geq 0$ or $0 > \max\{R(\theta), R(1)\}$, the leader's stage-2 payoffs are not affected by her decision (the follower's investment decision is independent of m). In a separating equilibrium, the leader announces (so that $\hat{\theta}(A|\bar{\mu}) = 1$) if the stage-1 profits are higher than from not announcing off equilibrium ($\hat{\theta}(\varnothing|\bar{\mu}) = 0$), that means, if $\tilde{\pi}_G(1) \geq \tilde{\pi}_G(0)$ or

$$\pi_{GB} \geq (1+\sigma)\,\pi_{GB} \tag{23}$$

which holds true for all $\sigma \leq 0$. In a pooling equilibrium, the leader does not announce (so that $\hat{\theta}(\varnothing|\bar{\mu}) = \theta$) if the stage-1 profits are higher than from announcing off equilibrium ($\hat{\theta}(A|\bar{\mu}) = 1$), that means, if $\tilde{\pi}_G(\theta) \geq \tilde{\pi}_G(1)$ or

$$(1 + \sigma (1 - \theta)) \pi_{GB} \geq \pi_{GB} \tag{24}$$

which holds true if $\sigma (1 - \theta) \geq 0$ and thus for all $\sigma \geq 0$. Also note, the leader is indifferent between $m = A$ and $m = \varnothing$ only if $\sigma = 0$; there are no mixed strategy equilibria for $\sigma \neq 0$.

Proof of Proposition 4

The follower's equilibrium strategies follow by the assumption of $R(1) \geq 0 > R(\theta)$. Moreover, by equation (12) violated, the follower's net benefits from R&D are increasing in $\hat{\theta}$ (Lemma 4) so that $R(1) > R(\theta) > R(0)$.

1. For the leader's strategy, first consider a separating equilibrium, $\mu_G = 1$. The leader's payoffs when it announces (and the follower invests in R&D) are

   $$\tilde{\Pi}_G(\hat{\theta}(A|\,(1,0))) = \pi_{GB} + \pi_{GG} + \gamma\lambda - \rho_G \psi_{F|G} = \tilde{\Pi}_G(1)$$

   If (off equilibrium) the leader does not announce (and the follower does not invest in R&D because with beliefs $\hat{\theta}(\varnothing|\,(1,0)) = 0$ we have $R(0) < 0$), then her payoffs are:

   $$\tilde{\Pi}_G(\hat{\theta}(\varnothing|\,(1,0))) = (1 + \sigma) \pi_{GB} + \pi_{GG} + \gamma\lambda = \tilde{\Pi}_G(0)$$

   with $\gamma\lambda - \rho_G \psi_{F|G} \geq 0$. A separating equilibrium thus exists if $\tilde{\Pi}_G(1) \geq \tilde{\Pi}_G(0)$. Rearranging this condition and using the expressions for ρ_G and $\psi_{F|G}$ yields condition (17) in the Proposition.

2. Now, consider a pooling equilibrium, where the leader does not announce in equilibrium, $\mu = 0$. On the equilibrium path (observing $m = \varnothing$ and $\hat{\theta}(\varnothing|\,(0,0)) = \theta$), the follower does not invest in R&D. The leader's equilibrium payoffs are:

   $$\tilde{\Pi}_G(\hat{\theta}(\varnothing|\,(0,0))) = (1 + \sigma (1 - \theta)) \pi_{GB} + \pi_{GG} + \gamma\lambda = \tilde{\Pi}_G(\theta)$$

   If (off equilibrium), the leader announces, $m = A$, then $\hat{\theta}(A|\,(0,0)) = 1$ and the follower invests in R&D. The leader's off-equilibrium payoffs are:

   $$\tilde{\Pi}_G(\hat{\theta}(A|\,(0,0))) = \pi_{GB} + \pi_{GG} + \gamma\lambda - \rho_G \psi_{F|G} = \tilde{\Pi}_G(1)$$

   A pooling equilibrium exists if $\tilde{\Pi}_G(\theta) \geq \tilde{\Pi}_G(1)$. Rearranging this condition and using the expressions for ρ_G and $\psi_{F|G}$ yields condition (18) in the Proposition.