Little Firms and Big Patents

A Model of Small-Firm Patent Signaling

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Abstract

Patent strategies of small technology-intensive firms are difficult to explain with standard incentive arguments based on intellectual property rights. This paper develops a rationale for patent filing as a disclosure strategy.

We develop a two-sender signaling game to study patenting incentives of two technology start-ups to file in a large-scale patent system with the goal to attract a user firm. Both start-ups may decide to invest in costly modification of their patent application before filing. The paper identifies a separating equilibrium in which the high-quality inventor files and so separates from its technology competitor.

Of particular interest is the study of pooling and semi-separating equilibria, as well as the impact of subsidies. We find that a higher quality of a country's inventions, reflected in the possible innovative steps and thus in higher expected profits for foreign user firms, may increase the chance of the relatively lower-quality inventor to enter international technology markets.

JEL Classification : $D21$, $D43$, $O31$, $O33$.

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1 Introduction[1]

Patents play a central role in making technology markets work. The standard view is that patents, by assigning intellectual property (IP) rights, turn inventions into tradeable technologies. Tradeability enables a division of innovative labor that typically takes place between small technology-based firms on one side, and large technology-seeking multinationals on the other.[2]

The latter are capable of commercializing new technologies as part of their products and so permit technology startups to engage in technological specialization instead of seeking financing.[3] At the core of the "licensing for royalties" paradigm[4] stands the idea that licensing contracts are used to allow technology trading, both in horizontal markets among rivals and in vertical markets between nonrival partner firms.[5]

1.1 Disclosure strategies and the signaling aspect of patent filing

This standard view also holds for markets of future technologies.[6] This is important because technology start-ups rarely find themselves in the privileged position of seeing their first invention directly becoming part of a ready-to-market product. The strategies used by small inventor firms to enter worldwide technology markets may involve the patent process in a particular way.[7] Whether still in the patenting process or already patented, their inventions may draw the attention of technology user firms that routinely skim patent sources. This works because patents, and in most countries, patent applications lead to official documents, also published in a journal or a gazette. The public

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[2]Von Hippel (1990).

[3]Arora et al. (2001).

[4]Lemley (2001).

[5]For an up-to-date overview on the issue see Gambardella (2005). The issue of small firm patenting has become more and more relevant as the literature confirms the importance of IP for smaller firms to start-up and invest in technology. See in particular Gambardella et al. (2007).

[6]Arora et al. (2001).

[7]It is worth noting that even licensing can be triggered by patenting just one strong invention, that applies to a high-volume product of a large corporation. (Grindley and Teece, 1997, p. 32). Also Gans and Stern (2003) have argued that the existence of a larger patent portfolio is not always necessary for entering technology markets.

availability through filing may help inventors to seek their users. The inventions of start-ups may turn out not to be licensed as an implementable part of a product or process. However, user firms will often see the disclosed invention as promising enough to warrant approaching the inventor for an R&D joint venture or an alliance. In short: tailor your disclosure to the needs of multinational firms and take out a patent so they know you - as long as you beat other competitors in terms of usefulness of your technology, you'll make it. Opportunity knocks. [8]

Firms patent for many reasons. So far, the literature on patent strategies has extended this view by analyzing why large firms use their IP rights strategically, why they engage in patent litigation[9], why they invent around,[10] why they build patent thickets around their competitors inventions,[11] or why they want to publish defensively in other sources.[12] But it is the general way we think about patents that has undergone a fundamental change in the past ten years. In a first step toward reaching a new understanding, Hall and Ziedonis (2001) have rejected standard arguments of patent races in their analysis of the U.S. "patent paradox," instead stressing the importance of complex patent portfolios for the management of IP rights. While their work and related papers on large firm patenting[13] have made us aware of the impact of patents when in the hands of large players, the literature on small firm patenting behavior has, by and large, remained in the the shadows. Although some research has been done on the strategic value of patents, in particular in the work of Rivette and Kline (2000), Harabi (1995), and Kabla (1996), disclosure strategies of small firms were generally explained by small firms' IP rights and the difficulties to enforce them.[14] However, studies do exist studies that include disclosure strategies in their analysis.[15].

Recent contributions of legal scholars such as Long (2003) have criticized in particular the incentive view of IP as too simple since it does not sufficienctly encompass the benefits of disclosure:

> "Because the simple view relies on the assumption that disclosing information represents a loss to the patentee, however, it fails to contemplate that patentees might actually benefit from the information disclosure, even if they were to receive no protection in return."[16]

While our paper uses a concept different from Long, it is important to point out that the disclosure

[8] Astebro and Dahlin (2005) define opportunity in the larger context of ex-ante technological significance.
[9] Lanjouw and Schankerman (1997).
[10] Glazier (1995).
[11] See Bessen (2003).
[12] Bar (2006), Baker and Mezzetti (2005).
[13] See Gallini and Scotchmer (2001) for an overview.
[14] See e.g. Mogee (2000).
[15] See Arundel and Steinmueller (1998), as well as Audretsch (2002).
[16] Long (2003), p. 637.

argument is now being backed by studies on small firm patenting, such as Davis' (2006) research on Danish firms in three different industries:

> "The signalling role of patents was frequently emphasized, not only to warn off potential competitors, but also (similar to respondents in the two other industries) to attract the interest of customers and potential business partners. [..] Our respondents declared that applying for a patent showed that the firm was seriously committed to a particular line of research. It was a way to get one's name in the databases, where others searched to find out who was doing what."[17]

1.2 Explaining an empirical puzzle

Technology start-ups located in transition countries such as Eastern Europe, Asia and South America[18] have often reached a level of technological capability that could warrant participating in international technology markets.[19] As they seek competitive advantage over rivals, they need to make decisions on whether and how to enter global markets. Current research shows that small firms in transition countries often adopt a dual strategy that permits them both to produce for their home country and to use their capability to enter global technology markets.[20]

While U.S. startups are in the privileged position of facing a large-scale national patent system that both secures their IP rights *and* offers a credible disclosure channel that is routinely skimmed by virtually all multinational user firms,[21] this does not hold for small firms located in developing or transition countries. Start-ups in such regions may well have access to their national patent office, and holding a patent in their country will secure their IP rights. However, large technology users may often ignore particular patent system because of language barriers, hurdles of accessibility, or simply the lacking reputations of firms located in a particular country.[22]

Although their technology may be generally sound enough to pass the patenting criteria of large-scale patent systems, small firms in transition regions could still refrain from patenting abroad, as the well-documented case of Eastern Germany reveals. East-Germany's mostly small firms under-

[17] Davis (2006), p. 257.

[18] See WIPO (2006) for a discussion of particular cases.

[19] See Athreye and Cantwell (2007) on countries with specialization patterns in particular technologies as well as Gambardella et al. (2007).

[20] See Rousseva (2008).

[21] For an overview see Burrone and Jaiya (2004).

[22] This also relates to the more general question of credibility of disclosure channels. The reason we develop a signaling model using patenting follows from the fact that open source disclosure or directly approaching a particular user firm is considered not viable.

went an abrupt change, forcing them to give up their technological environment and their usual markets when joining (West-) Germany's innovation and legal system in 1990. The comparison of domestic and EU-wide filing of German firms seems particularly appropriate because of the institutional similarity of the German and the European Patent Office (EPO), which Paci and Sassu (1997) have pointed out. This argument holds less strongly for other EU countries.[23] While their domestic patent applications quickly reached the level of West-German firms, their foreign filing activity had been particularly low until 1996 (see *Fig. 1* below).

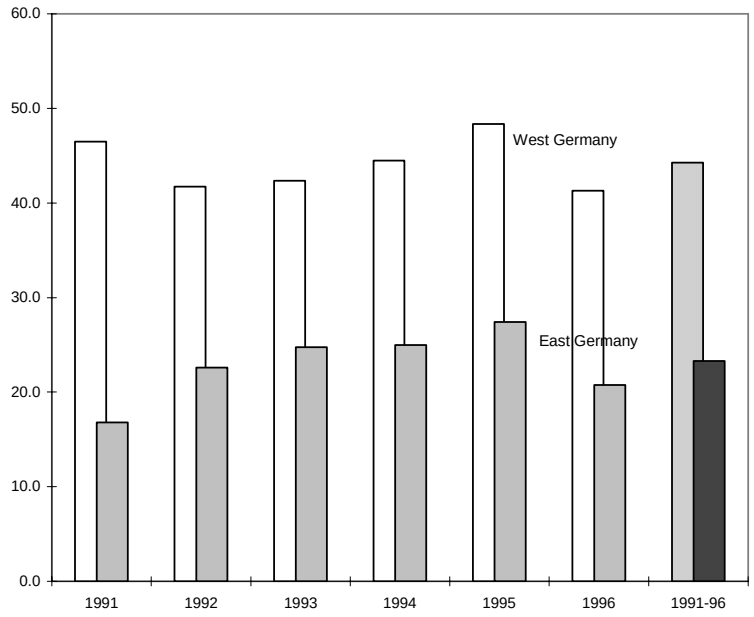

Fig 1: Percentage of patent applications in at least two countries normalized to their domestic patent applications of West- and East-German firms. Date based on IFO patent statistics. Values for 1996 are without USPTO applications. Source: Gick (1998).

The continuously low international filing percentage is particularly puzzling since East-German firms had access to large-scale subsidies that covered patent filing and related expenses that would usually prevent firms from patenting outside of their domestic system.[24]

[23]One may expect that inventions that have already been granted a German-wide patent will most likely reach EU-wide patent protection as well. I owe this thought to Mark Schankerman.

[24]See WIPO (2006), and Fier and Harhoff (2002).

While our analysis is motivated by this case in point, our paper does not focus on East-German SMEs as a particular case. Instead, our paper aims to close a gap that has become quite evident over the past years. On one side, the empirical literature on large firm patenting continues to make a case for small firm patenting behavior but fails to explain the typical disclosure strategies of start-ups in the presence of more advanced technology competitors. On the other, newer contributions reveal that small inventor firms are encompassing disclosure in a different way, but these studies typically do not offer a discussion from a management strategic perspective. Thus, this paper is a first pass at analyzing the disclosure strategies of small firms under technological competition.

The general view of our paper is that small inventor firms, conscious of their own technological solution relative to other inventor firms' findings, may want to either improve and disclose to match up with their competitor or decide not to file if they see that their technology cannot reach their level. We do not deny that start-ups will primarily aim to patent their inventions in their home country in order to discourage outright imitation and secure their monopoly position in their primary market. However, the literature suggests that disclosure motive is often more important, in particular when it comes to explain small firm's filing behavior in larger patent systems.

1.3 Literature review

Besides the previosly-discussed literature on innovation, technology and IP management, there are three more strands of the economics literature that are related to this work.

First, our paper relates to the existing literature on patent signaling, which has traditionally modeled the effects of information disclosure on firm strategies and incentives. That patents may reveal important information to competitors has been already analyzed in the seminal paper of Horstmann et al. (1985). Assuming private information about profits, they show that firms will only patent a fraction of their research when imitation is possible. In equilibrium, firms play a mixed strategy between disclosing and not disclosing.

In a more sophisticated paper, Anton and Yao (2003) study the trade-off between signaling capabilities and the risk of transferring knowledge. Since patents come with limited exclusivity - meaning that they can be ruled invalid when challenged in court - an inventor may profit from signaling strong capability when information is private and the amount of disclosure affects the probability of the patent's validity. The outcome depends on the costs and benefits in the down-stream market competition.

Furthermore, Anton and Yao (2004) analyze three aspects that relate to the strength of IP rights. Because of asymmetric information, firms may optimally manage their intellectual property in the interplay between property rights, disclosure and imitation. Typically, small innovations may often become patented and remain unimitated, while larger innovations are optimally protected by patents and secrecy, with implicit licensing among competitors. In turn, large innovations are not patented but are instead ideally kept secret.

Although our model does not particularly focus on licensing, it should be mentioned that work by Gallini and Wright (1990) on licensing under asymmetric information is similar in spirit to our setting. In their paper, a licensee may be less informed about the quality of an invention than the inventing firm that holds a patent and is aiming to enter a licensing agreement. The licensor/inventor can make a contract offer to the (known) licensee. As in an informed principal-agent setting, the form of the contract offer now reveals information about the quality of the technology, with the licensor requesting an output-based royalty or a fixed fee to be paid *ex ante*. In equilibrium, a licensor with the "high-cost" innovation separates itself from its competitor by offering a symmetric information contract and extracts all the rents, while an inventor with a better innovation deals with the problem of imitation.

Second, our model reflects developments in the recent literature on two-sender signaling models. It most directly relates to papers in the price-quality signaling literature, such as the work of Hertzendorf and Overgaard (2001) and of Fluet and Garella (2002), who extend simpler monopoly signaling and limit pricing models. In these papers, two oligopolists use price and advertising expenditure to signal their qualities to consumers. As in our model, both senders know both sender's qualities and the receiver is indifferent with regard to the choice of sender.[25] However, unlike monopoly signaling models, our paper takes into account different disclosure levels of *actual* competitors when determining a firm's equilibrium patenting strategy. The equilibrium construction with three players is different in spirit from monopoly signaling models. To our knowledge, such models have not yet been used to model disclosure of information under technology competition.

In a product safety context, Daughety and Reinganum (2005) develop a two-sender model to explain the trade-off between confidentiality and openess. The option for confidential settlements gives rise to asymmetric information: firms facing tort litigation may incorporate lower average safety compared to a regime involving secrecy, whereas openness excludes confidentiality but renders product safety observable to consumers. Daughety and Reinganum (2007) limit signaling to price and provide a setting with horizontally and possibly vertically differentiated products. The two

[25]For an overview, see Riley (2001).

senders are not informed of their opponent's quality. Confidentiality then becomes a tool by which the firm can prevent consumers and the competitor from learning its quality. Last, Daughety and Reinganum (2008) provide a multifirm model with one representative consumer and differentiated substitute products. Their paper combines a price-quality signaling model with a model of imperfect product market competition and horizontally differentiated goods, and includes applications to tort reform and professional licensing.

Work of Garella and Peitz (2000 and 2007) is related to this literature. Contrary to the monopoly signaling paper of Bagwell and Riordan (1991), which models two quality levels and explains upward price distortion for the high quality firm, Garella and Peitz (2000) considers that one firm may signal quality through the choice of its *mode of selling*; selling in vertically-unintegrated markets enables high-quality firms to choose certification. Closer in spirit to our paper is Garella and Peitz (2007), which analyzes marketing alliances between competitors as a quality signal for consumers. While in our paper a known and potentially more advanced technology competitor may keep the lower-quality firm from filing, Garella and Peitz use an established firm as provider of information about product quality. An unknown brand may want to enter an alliance, and the established firm will typically accept the entrant if it is of high quality. Although we don't model entry into product markets, the similarity to our paper arises from the lower quality firm's need to reach a disclosure level determined by its more advanced competitor.

Third, our setup has some affinity to the literature on certification and standard setting organizations (SSO).[26] Although our model is specifically based on a single disclosure and does not encompass patent pools or standards that exclusively emerge from joining an SSO, our paper relates to some sideline features of this new strand of literature. Large-scale patent systems are attractive SSOs because of their size, which allows inventors to gain user firms' attentions. Smaller patent systems are limited in scale and thus are not as effective diffusors as large-scale systems. In our paper, the binary choice of patenting or not patenting makes the setting similar to strategic arguments used in the literature on forum shopping.[27]

Our paper is structured as follows: Section 2 will lay out the model and establish that more advanced firms separate from their less qualified technology competitors (Proposition 1). It will also

[26] Lerner and Tirole (2006).

[27] From the sponsor's perspective this will make different disclosure strategies optimal for different certifiers. However, certifiers may not necessarily want to make it easier for foreign firms to access their particular patent system since this may strengthen the competitiveness of foreign firms over domestic firms. This argument has been used in favor of an EU "community patent" that internalizes such policy externalities. For a discussion see van der Horst et al. (2006).

discuss the existence of pooling and semi-separating equilibria under particular payoff regimes, thus providing the rationale behind why disadvantaged firms may level up with their competitor and disclose (Proposition 5). Section 3 will show that subsidies are generally ineffective in mitigating the situation and incentivizing disclusure. Section 4 will conclude. The discussion of one subcase and the proofs of all propositions can be found in the appendix.

2 The model

2.1 General setup

Consider an industry in which two domestic start-ups file for a patent in a larger patent system, and both compete for a tie-up with an international user firm F that has the resources to commercialize the technology.[28] What are the patenting strategies of the two start-ups? What makes each presume that its technology will receive enough attention from F in the presence of its competitor?

We assume that each start-up knows that if its technology cannot be utilized by F, a disclosure through patent filing may not trigger any partnership; it simply is not a significant or relevant technology for F. F does not know either firm before skimming the patent source, but firms i and j possess complete knowledge of the possible value of each other's technology. Whenever i faces high incremental costs in turning its technology into one that may be applicable to F's needs, it is intuitive to argue that i will not file internationally. It cannot change the fact that j's chances to be picked by F are higher. Conversely, should firm i have lower incremental development costs to reach a disclosure level that attracts F, i may have an interest in filing.

To label firms i and j now according to their *relative* type, H and L, we introduce a move of nature. Without loss of generality, the two firms are now independently drawn out of a continuous set of firms. This draw not only eliminates the problem of dealing with types that are equal in their true technological quality, but also reduces the problem of asymmetric information. F is still uninformed about the realization of two possible events, namely

- *Event HL:* Firm 1 is of type H , firm 2 of type L
- *Event LH:* Firm 2 is of type H , firm 1 of type L.[29]

[28]The division "domestic" versus "foreign" comes without loss of generality and follows intuitively from empirical observation. One may as well assume that the two start-ups are located in two different countries outside the U.S., both deciding whether or not filing for patent at the USTPO.

[29]To introduce such a move is common in the two-sender literature on signaling. See e.g. Hertzendorf and Overgaard (2001).The *actual* level of disclosure indeed differs, and the two types of firms may not really be of high and of low

This *ex ante* symmetry of two cases is helpful in considering both firms and their relative quality of innovation. F does not know which event occurs but knows the probability distribution. We assume it holds prior beliefs such that event HL occurs with probability ν, and that event LH occurs with probability $1-\nu$.

The two firms signal their receiver-dependent quality by filing in a patent system that F reads. In the eyes of F, the two firms are capable of choosing a continuum of disclosure qualities, with $\delta \in [0,1]$. This variable can be interpreted as the detail provided in the patent application. It is normalized to 1 in the case of the highest possible quality being disclosed.[30] Each firm has a binary choice between filing and not, and has private information about the competitor's quality.

Contingent on the observation of a disclosure pair (δ_1, δ_2) obtained through skimming the patent literature, firm F updates its beliefs and chooses one firm with which to form a partnership.[31]

2.2 Payoffs

Let $\gamma(\delta_i, \delta_j) \in \{i, j, 0\}$ denote F's choice of partner, where $\gamma(\delta_i, \delta_j) = 0$ implies that F does not form a partnership with either firm. Then, firm i's revenue function can be defined as a function of F's choice:

$$R_i\left(\gamma(\delta_i, \delta_j)\right) = \begin{cases} 0 \text{ if } \gamma(\delta_i, \delta_j) \in \{j, 0\} \\ R \ > 0 \text{ if } \gamma(\delta_i, \delta_j) = \text{i.} \end{cases} .$$

Firm i's cost function $C_i(\delta_i) = C_f + c_i(\delta_i)$ covers the fixed patenting costs (patent fee, etc.) C_f, and variable costs $c_i(\delta_i)$ of incremental development, depending on the domestic firm's type. It is of course possible for a firm to file an identical patent internationally; however, each domestic firm may also translate its invention into an international patent application to reach F's attention.

Each firm faces convex development costs, which are specified as follows. Firm i, unobservable by F, invests in incremental development to reach a specific level of disclosure quality or detail provided, δ_i, and innovates by spending the type-dependent variable development costs $c_i(\delta_i)$. When taking out a patent, the firm pays the fixed costs C_f. In a two-type world, we assume the type dependent variable cost functions c_L and c_H, which permits us to illustrate the total cost function for firm i as $C_i(\delta_i) = C_f + c_i(\delta_i)$, a function of disclosure quality, and $c'_L > c'_H$. Firm L has higher

knowledge, but that F, given profitability expectations, sees both differently.

[30] As a borderline case, we assume that a firm choosing a signaled quality level $\delta = 0$ does not incur any additional costs of disclosure, nor does it pay any fixed costs of patent applications.

[31] This view is in line with Cohen's (1995) concept of technological opportunity, which reflects the cost of achieving some normalized unit of technical advance.

marginal costs to reach a significant relevant technology. Since patenting involves a fixed cost plus a variable cost that is increasing in the level of detail provided (and the type), the level of detail is observable and can act as a signal of type. In other words, a very elaborate and detailed patent application costs more, but more detail in the patent application does not improve the technology. It is important for an understanding that F does not care about δ_i, *per se*, but it does care about what it signals about the type of the inventor firm.

Firm i's profits are revenues minus costs, both functions of (δ_i, δ_j) and of F's decision rule, γ :

$$\Pi_i(\delta_i, \delta_j; \gamma) = R_i(\gamma(\delta_1, \delta_2)) - C_i(\delta_i).$$

To define F's prior beliefs, we call $\mu^i(\delta_i, \delta_j)$ firm F's assessment that firm i, when disclosing δ_i, holds competencies (innovation qualities) that belong to type i.

F's payoffs may typically include a ranking of $\Pi_F^H > \Pi_F^L > \Pi_F^N$. While we later permit cooperation payoffs to exceed those of noncooperation in expectation, we do not further discuss this setting here. This ranking, along with additional assumptions, would justify any action of F as profit enhancing.

F's profits do not depend on the level of disclosure of either domestic firm but on the type of firm with which it is cooperating. The foreign firm is strictly worse off when cooperating with L because the costs of cooperating with L are higher. L's technology is less useful, which would give a negative net value to F when cooperating with L.

Under full information, F picks firm H as cooperation partner. If F is not informed about the state of nature, asymmetric information will affect the outcome. By patenting, a firm may reduce the informational asymmetry.

Since we study a model with two *actual* technology competitors, the analysis depends a great deal on the payoff situation of F and on the consequential chances of being chosen as its technology partner. In cases with high profit expectations it may be worth aiming at being chosen randomly, while in other cases firm L can never win a cooperation.

This analysis is based on a consideration of L's options in a broad setting that takes different equilibrium situations into account. We rule out additional strategic behavior that would make the setting less illustrative: F does not produce for the small domestic market of the two competitors, nor does it attempt to enter the domestic market after an R&D cooperation with one of them. Similarly, none of the domestic firms files an international patent to produce directly for the foreign

market in order to compete with F after the R&D stage.[32]

2.3 Equilibria

The comparison of F's *ex-ante* payoff $\nu\Pi_F^H + (1-\nu)\Pi_F^L$ from cooperating to the non-cooperation payoff Π_F^N can be split into two general cases that characterize firm F's behavior. Given that F believes that HL occurs with $\nu \geq .5$, two relevant payoff regimes can be singled out:

• **Payoff Regime 1.** Here, the payoff when not cooperating exceeds the expected payoff of cooperation: $\nu\Pi_F^H + (1-\nu)\Pi_F^L < \Pi_F^N$. In this case, F in expectation chooses to not cooperate with either firm.

• **Payoff Regime 2.** In this second scenario, the foreign firm has expected profits that exceed the default payoff under noncooperation, with $\nu\Pi_F^H + (1-\nu)\Pi_F^L \geq \Pi_F^N$. Cooperation is much more likely in this situation. When priors are diffuse, firm F randomizes, but under priors of $\nu > .5$ it picks firm 1 as its cooperation partner. This is all under the assumption that no additional information is available.

With two real senders, the equilibrium concept is defined as follows:

Definition 1 Labeling "H", "L" and "F" the three players, a Perfect Bayesian Equilibrium (PBE) is defined by a strategy profile $(\delta_H, \delta_L, \gamma)$ and a belief system $\mu(\delta_H, \delta_L)$ for firm F such that

(i) δ_H, and δ_L are mutually best replies given $\gamma(\delta_H, \delta_L)$;

(ii) $\gamma(\delta_H, \delta_L)$ maximizes firm F's utility given its beliefs $\mu(\delta_H, \delta_L)$;

(iii) the belief system $\mu(\delta_H, \delta_L)$ is consistent with the strategies adopted by firms H and L.

The following consistency requirement for equilibrium belief systems holds:

(iv) $\mu^i(\hat{\delta}_L, \hat{\delta}_H) = 0$ *and* $\mu^j(\hat{\delta}_H, \hat{\delta}_L) = 1$ *if* $\hat{\delta}_L \neq \hat{\delta}_H$ and

(v) $\mu^1(\delta, \delta) = \nu$ *for all* δ.

F's equilibrium strategy is characterized by

(vi) $\hat{\gamma}(\delta_i, \delta_j) = i$ *if* $\mu^i(\delta_i, \delta_j) = 1$ *and* $\hat{\gamma}(\delta_1, \delta_2) = 0$ *if* $\mu^1(\delta_1, \delta_2) = \nu$ (Payoff Situation 1),

(vii) $\hat{\gamma}(\delta_1, \delta_2) = 1$ *if* $\mu^1(\delta_1, \delta_2) = \nu$ (Payoff Situation 2).

[32] It is not difficult to relax these assumptions and to permit for cross-licensing arguments to apply in the sense of Grindley and Teece (1997). For analytical simplicity we want to abstract from such reasoning.

Next we use the foreign firm's beliefs at out-of-equilibrium disclosures to determine which equilibria are supported by the out-of equilibrium beliefs.

First, we consider a situation in which F maintains its prior beliefs independent of the two firms' disclosures. It is easy to see that in this situation an equilibrium exists in which neither firm discloses because disclosure is costly and cannot influence F's decision. This equilibrium is trivial. It exists because of firm F's refusal to update. We now rule out such beliefs and will maintain the following out-of-equilibrium beliefs throughout the remainder of the paper.

Definition 2 Out-of-equilibrium beliefs.

For any out-of-equilibrium disclosure pair (δ_i, δ_j) :

(i) $if\ \max(\delta_i, \delta_j) < \hat{\delta}_H$, then $\mu^1(\delta_1, \delta_2) = \nu$,

(ii) $if\ \max(\delta_i, \delta_j) \geq \hat{\delta}_H$, then $\mu^i(\delta_i, \delta_j) = \begin{cases} 1\ if\ \delta_i > \delta_j, \\ 0\ if\ \delta_i < \delta_j, \text{ and } \mu^1(\delta, \delta) = \nu. \end{cases}$

In words, part (i) tells that whenever both firms disclose less than $\hat{\delta}_H$, F retains its prior beliefs. In turn, (ii) reveals that when at least one firm discloses at level $\hat{\delta}_H$ or higher, F believes that the firm disclosing the higher level is of type H. This is intuitive since the H-type firm has a lower cost of disclosure at all levels. In the same setting, whenever the domestic firms disclose the same amount, the prior is maintained, since no further useful information is disclosed to F.

Under these out-of-equilibrium beliefs, the two domestic firms may affect F's decision if they disclose a sufficient amount. The model now leads to a consistent view in which F punishes low disclosures whenever believing the firm under consideration is of type L. However, since F cannot believe that *both* are of type L, it will resort to its prior belief in this case.

We now examine the conditions for equilibrium outcomes in the following payoff scenarios and cases that define the prior beliefs:

2.3.1 Payoff Regime 1: $\nu\Pi_F^H + (1-\nu)\Pi_F^L < \Pi_F^N$

Case 1a: $\nu \geq .5$ [33]

This case represents the first of two parametric cases. It refers to a situation in which the foreign firm is not completely uninformed and may hold prior beliefs in favor of firm 1. What follows is an analysis of why signaling is needed according to F's payoff condition $\nu\Pi_F^H + (1-\nu)\Pi_F^L < \Pi_F^N$

[33] For other priors, the foreign firm switches from case HL to LH because of symmetry.

and a prior of $\nu \geq .5$. F needs a separating signal to tell the two firms apart. Otherwise, the given beliefs do not sustain cooperation.

Existence. We now analyze the conditions that induce the domestic firms to disclose these signals. In this sequence, when speaking of the domestic firms' payoffs, we use the notation (δ_H, δ_L). The superscript used for the domestic firms' payoff denotes the putative mode of cooperation, where C stands for cooperation between F and the firm under consideration. O indicates cooperation between F and the domestic competitor, and N, as before, non-cooperation. Given that firm F picks one firm only, separating requires the following two IC constraints to hold:

$$\Pi_H^C(\delta^*, 0) \geq \Pi_H^N(0, 0) \qquad \text{(IC H)}$$

and

$$\Pi_L^O(\delta^*, 0) \geq \Pi_L^C(\delta^*, \delta^* + \varepsilon) \geq \Pi_L^N(\delta^*, \delta^*). \qquad \text{(IC L)}$$

with $\varepsilon \geq 0$.

Solution. (i) (IC H). Let $\Pi_H^N(0, 0) = 0$. This reduces the observation to $\Pi_H^C(\delta^*, 0) \geq 0$. Since $\Pi_H^C(\delta^*, 0) = R - (C_f + c_H(\delta^*))$, (IC H) holds if and only if $R \geq C_f + c_H(\delta^*)$, namely if H's expected cooperation benefits R at least cover its patenting and development costs.

(ii) (IC L^N). As long as L cannot benefit from an increase in its rival's cost of disclosure, $\Pi_L^O(\delta^*, 0)$ is zero. The R.H.S. however is negative since $\Pi_L^N(\delta^*, \delta^*)$ entails signaling costs of $C_f + c_L(\delta^*)$. Under reasonable assumptions, (IC L^N) is always fulfilled.

(iii) (IC L^C). For the same reason as in (ii), we set $\Pi_L^O(\delta^*, 0) = 0$. (IC L^C) holds if and only if $R \leq (C_f + c_L(\delta^* + \varepsilon))$. Since $\lim_{\varepsilon \to 0} (c_L(\delta^* + \varepsilon)) = c_L(\delta^*)$, the L-type firm would not find it profitable to overshoot δ^* even if it could ensure F's cooperation.

Proposition 1 (Technologically advanced firms separate from less advanced): *Under the given assumptions on belief structure and payoff conditions in Case 1, the game has a continuum of separating PBE, in which H discloses exactly the disclosure level δ^* and L discloses 0, with δ^* satisfying $C_f + c_H(\delta^*) \leq R \leq C_f + c_L(\delta^*)$.*

Note that the set of δ^* defined according to this proposition is non-empty because $c_H(\delta^*) < c_L(\delta^*)$ for all $\delta > 0$.

Equilibrium Refinements.[34] The continuum of separating PBE however occurs as long as firm F does not update its beliefs for the necessary minimum level of δ^*. Suppose there is an equilibrium in which firm F would hold the new, unreasonable belief structure:

$$Prob \text{ (firm 1 is of type H } \mid \delta_1, \delta_2) = \begin{cases} 1 \text{ if } \delta_1 = \delta^* + \alpha \text{ and } \delta_2 \neq \delta^* + \alpha \\ \nu \text{ if } \delta_1 = \delta_2 \\ 0 \text{ otherwise.} \end{cases}$$

Under this belief structure, any signal less than $\delta^* + \alpha$ will be interpreted by firm F as stemming from L. Firm H would be willing to disclose within the interval $[\delta^*, \delta^* + \alpha]$, while firm L would not. In other words, to signal within this interval would constitute an equilibrium-dominated strategy for L.

This can be checked as follows: first, assume that by sending such a signal, firm L makes F believe that it is of type L. Then, sending this signal would not have been necessary, since a lower disclosure would have led to the same result at lower costs.

Second, if firm L would make F believe that its type is H by sending such a signal, then this disclosure would be at too high a level. L would need to behave optimally after, and would not want to mimic H. Thus, any signal in the interval $[\delta^*, \delta^* + \alpha]$ would be equilibrium dominated for firm L.

Also, in neither of the two cases would firm F assign any positive probability to a signal observed in the interval $[\delta^*, \delta^* + \alpha]$ stemming from firm L if F has a reasonable belief structure. The interesting result is that the separating PBE described in case 1 cannot be a sensible prediction as long as firm F maintains the new belief structure. Since we limit the observation to equilibrium responses and to reasonable beliefs, should the separating PBE be a sensible prediction, we can drop the assumption that firm F will maintain any belief structure of this kind.

Thus, the analysis narrows down to a unique separating PBE that involves the lowest amount of disclosure for the type-H firm consistent with (IC L^C): that is, δ^*defined by $R = C_f + c_L(\delta^*)$.

[34]The domination based refinement concept follows the exposition of the more general case in Mas-Colell et al. (1995), p. 471.

• **Nonexistence of Pooling Equilibria.**

Proposition 2 (Under Payoff Regime 1 the technologically more advanced firm can always avoid being pooled with its competitor) *No pooling equilibria exist under disclosure, given the existing belief structure.*

2.3.2 Payoff Regime 2: $\nu\Pi_F^H + (1-\nu)\Pi_F^L \geq \Pi_F^N$

Case 2a: $\nu = .5$ This case is studied in the appendix.

Case 2b: $\nu > .5$ With priors of $\nu > .5$, F now chooses firm 1 whenever the two firms disclose the same amount and, in addition, the game has equilibria under $\nu\Pi_F^H + (1-\nu)\Pi_F^L \geq \Pi_F^N$. Thus, in general, firm 1 does not need to outbid firm 2; leveling up with H now becomes a sufficient strategy to be picked by F. As stated before, the three-player analysis now delivers a great deal of new insight into when L can level up with H?

Recall **Definition 2** on out-of-equilibrium beliefs. Using the same beliefs, we can now specify a particular $\delta^{*,}$ in this case defined by $R = C_f + c_L(\delta^*)$. Then, for any out-of-equilibrium disclosure pair, F's beliefs can be written as follows:

(i) if $\max(\delta_i, \delta_j) < \delta^*$, then $\mu^1(\delta_1, \delta_2) = \nu$,

(i) if $\max(\delta_i, \delta_j) \geq \delta^*$, then $\mu^i(\delta_i, \delta_j) = 0$ if $\delta_i < \delta_j$, and $\mu^i(\delta, \delta) = \nu$.

Proposition 5 (The less advanced firm L may win the cooperation with F under the given priors) *This game has a semi-separating equilibrium in which firm 2 discloses δ^* in the event LH and F awards the contract to firm 2, and both firms disclose 0 in the event HL and F awards the contract to firm 1.*

This result is of particular interest. The immediate interpretation is that separation can be mitigated when the expected profits of the user firm are higher. Moreover, this result is similar to findings of other three-player models such as Garella and Peitz (2007). Since there are wasteful signaling costs involved, cooperation between the two senders would enhance social welfare in this setting: when firm 2 is selected by Nature as firm H, it would be profitable for Firm 1 to purchase the invention from Firm 2. In this case, Firm 1 would pay at least as much as Firm 2 firm would gain from patenting, then patent itself with a zero disclosure cost and receiving R from player F.[35]

[35] I thank an anonymous referee for this suggestion.

3 Subsidies

With two real senders in the regime we can now study the subsidization of patent applications.[36] In what follows, we analyze the typical form of Government subsidies, namely payments covering filing expenses.

Condition 2 (Framework for patent subsidization: information and procedures). *Government is not informed about the domestic firms' type. It offers subsidies of* $S = C_f^P$ *to both firms. This is known by each firm at the decision stage.*

Proposition 6 (Subsidization of filing costs cannot change the result when firms separate). *Government subsidies do not change the outcome of separating equilibria. No firm will keep its level of disclosure* δ^* *constant when subsidies are offered, thus subsidies lead to wasteful competition in that both firms can now increase their level of disclosure.*

This is less costly per unit of increase for firm H. H will now use the subsidy and disclose a higher level δ^*, depending on the additional level of disclosure that firm L can gain by receiving $S = C_f^P$. L will not disclose and the firms again separate. As a result, subsidizing patent applications has no effect. Total welfare is decreased since subsidization does not change the separating result.

In all cases treated here, patent subsidies are socially wasteful. Intuitively, as long as government cannot or does not want to target one firm that it subsidizes, the outcome does not change since the technologically more advanced firm H will always separate from L.[37]

The policy implication that follows is valuable. Covering the costs of filing cannot improve the disclosure quality. Public actors who cannot or do not want to target particular firms cannot change the result of separation: the L- firm will not apply for subsidies at equilibrium.

[36] The difference between one sender that can be of two types, and a two sender model becomes clear in the following illustration: if a sole firm were to play the game, a subsidy would imply a patenting shift from negative to positive should the subsidy have an impact. This would affect the equilibrium. With two real senders, the equilibrium outcome is not changed, except for costs, if the technology leader files at equilibrium.

[37] To change this outcome, Government would not only need to ensure that only L would receive subsidization. Since both firms know both firms' qualities it would be furthermore necessary that both L and H hold beliefs such that H will no longer disclose in equilibrium. In such case, L could be incentivized to disclose.

4 Conclusion

Patent filing of small, technology-intensive start-ups is no longer a marginal IP management activity that is readily explained by incentive arguments. This paper has examined small firms' disclosure strategies under technological competition. Whether start-ups will enter global technology markets depends on their ability to patent in large patent systems and consequently to gain potential acceptance by global user firms. Inventor firms will only decide to file if they see their technology as good enough to level up with the quality of their technology competitors.

Our analysis has led to three main results, which depend receiver's profit expectations and the underlying prior beliefs. First, under less favorable assumptions, inventor firms typically separate in that the higher-quality firm will file. Second, and more important from a managerial perspective, more optimistic profit conjectures may give the less advanced firm the chance to leapfrog and win a partnership. Disclosure is therefore more likely to expect in countries where firms are known for the innovative quality of their inventions.

Our results shed new light on the role of disclosure strategies of small firms that aim at entering global technology markets. The significance lies in the innovative step that their invention possesses for technology users, and not in the degree of patent protection. Start-ups typically know if their technology fits a particular product or product line and how well it fits compared to other inventions.

While our paper was a first pass at modeling patenting disclosure of small firms with the goal of analyzing the strategies that start-ups have to enter international technology markets, we also employ our model to address the impact of patent subsidies. We find that subsidies in general do not change the result of separation. Additional applications are left for future research.

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6 Appendix

6.1 Case 2a: $\nu = .5$

• Separating equilibria

Whenever observing $\delta_1 = \delta_2$, firm F is indifferent between choosing firm 1 or 2 as its cooperation partner. Since firm F's payoff does not depend on δ, there is no reason why firm F should not cooperate with either firm after observing $\delta_1 = \delta_2$, even if this would be below some threshold value $\overline{\delta}$ that can be reached by L. This threshold value can be close to zero.

F in this case sets its priors and thus chooses firm 1 with probability .5 as its partner when observing $\delta_1 = \delta_2$. Any positive probability of choosing firm 1 is a credible threat for firm 2 and vice versa, punishing the domestic firms' out-of equilibrium actions.

The conditions for which $(\delta^*, 0)$ forms a separating PBE rewrite

$$\Pi_H^C(\delta^*, 0) \geq .5 \cdot \Pi_H^C(0,0) + .5 \cdot \Pi_H^O(0,0), \qquad \text{(IC H')}$$

$$\Pi_L^O(\delta^*, 0) \geq .5 \cdot \Pi_L^O(\delta^*, \delta^*) + .5 \cdot \Pi_L^N(\delta^*, \delta^*), \qquad \text{(IC L}^{N}\text{')}$$

$$\Pi_L^O(\delta^*, 0) \geq \Pi_L^C(\delta^*, \delta^* + \varepsilon). \qquad \text{(IC L}^{C\,\text{'}}\text{)}$$

(i) (IC H'). Since H does not face reduced profits due to domestic competition, the constraint rewrites into $.5R \geq C_f + c_H(\delta^*)$. In words, the total costs of patenting and development need to stay below half of H's expected cooperation benefit. This makes (IC H') harder to fulfill than (IC H).

(ii) (IC L^{N}'). I already assumed for absence of domestic competition that $\Pi_L^O(\cdot, 0) = 0$. Then, the R.H.S. becomes $-(C_f + c_L(\delta^*))$, which is always fulfilled.

(iii) (IC L^{C}'). The R.H.S. reads $\Pi_L^C(\delta^*, \delta^* + \varepsilon)$. By overshooting, firm L triggers inference of H, implying that F will cooperate with L. Note also that (IC L^{C}') and (IC L^{C}) are the same constraints and can be re-expressed into $R \leq C_f + c_L(\delta^*)$.[38]

The following condition offers a suitable treatment of developing costs.

Condition 1 *(i) Development costs $c_H(\delta)$ and $c_L(\delta)$ are linear. In this case we restrict our attention to the situation in which $c_L - 2c_H > C_f$. It follows that $\frac{C_f}{c_L - 2c_H} < 1$, and any $\delta^* \in \left[\frac{C_f}{c_L - 2c_H}, 1\right]$ can be used to signal quality H.*

(ii) Development costs $c_H(\delta)$ and $c_L(\delta)$ are convex, $c_H(\delta) - 2c_L(\delta)$ is increasing in δ and $c_L(1) - 2c_H(1) > C_f$. We define $\bar{\delta}$ by $c_L(\bar{\delta}) - 2c_H(\bar{\delta}) = C_f$. Then, any $\delta^* \in \left[\bar{\delta}, 1\right]$ can serve as signal of type H.

Proposition 3 (Case 2a permits separation at many disclosure levels) *Under the given assumptions on belief structure and payoffs, the game has a continuum of separating PBE, in which H discloses exactly the disclosure level δ^*, and L discloses 0, with δ^* satisfying $2[C_f + c_H(\delta^*)] \leq R \leq C_f + c_L(\delta^*)$.*

Equilibrium Refinements. By applying the same domination based equilibrium refinements, the continuum of separating PBE is narrowed down to one unique equilibrium in which the smallest equilibrium disclosure δ^* is chosen. The exposition follows very closely to the one described in the previous case.

[38] Note again that $\lim_{\varepsilon \to 0} (c_L(\delta^* + \varepsilon)) = c_L(\delta^*)$.

• **Pooling equilibria: Existence**

I now examine if under the given system of beliefs there exist active pooling equilibria. This is the case if the following IC conditions hold:

$$.5 \cdot \Pi_H^C(\delta^*, \delta^*) + .5 \cdot \Pi_H^O(\delta^*, \delta^*) \geq \Pi_H^O(0, \delta^*), \qquad \text{(IC H P)}$$

$$.5 \cdot \Pi_L^C(\delta^*, \delta^*) + .5 \cdot \Pi_L^O(\delta^*, \delta^*) \geq \Pi_L^O(\delta^*, 0), \qquad \text{(IC L P)}$$

$$.5 \cdot \Pi_H^C(\delta^*, \delta^*) + .5 \cdot \Pi_H^O(\delta^*, \delta^*) \geq \Pi_H^C(\delta^* + \varepsilon, \delta^*) \qquad \text{(IC H}^C \text{ P)}$$

(i) Since $\Pi_H^C(\delta^*, \delta^*) = R - (C_f + c_H(\delta^*))$, (IC H P) rewrites into $.5R \geq C_f + c_H(\delta^*)$.

(ii) Similarly, I assume for firm L that $\Pi_L^O(\cdot, 0) = 0$. Then, (IC L^{o}P) reads, analog to (IC H P):$.5R \geq C_f + c_L(\delta^*)$.

(iii) The third IC condition ensures that the H type would rather pool than outbid L and win the contract with certainty. As in (i), the L.H.S rewrites into $.5R - (C_f + c_H(\delta^*))$, while the R.H.S. now reads $R - (C_f + c_H(\delta^* + \varepsilon))$. Since $\lim_{\varepsilon \to 0} (c_H(\delta^* + \varepsilon)) = c_H(\delta^*)$, (IC H^{C}P) rewrites into $.5R \geq C_f + c_H(\delta^*)$.

Proposition 4 (In Case 2a each firm can avoid pooling) *The game has no pooling equilibrium under disclosure.*

Proof. Suppose there exists a δ that leads to pooling. In this case, both firms win a cooperation with equal likelihood, and they receive $.5R - C_f - c_k(\delta)$, with $k \epsilon \{L, H\}$. Then, either type would be better off by moving from this given δ to a $\delta + \varepsilon$ to receive the contract with certainty. ■

6.2 Proofs.

Proof of Proposition 2. First, consider a candidate for a pooling equilibrium involving $\delta \geq \delta^*$. Both firms are incurring costs of disclosure but neither receives a contract with F. Thus, either firm would do strictly better by defecting to no disclosure.

Next, consider a candidate for a pooling equilibrium involving $\delta \leq \delta^*$, including $\delta = 0$. Similarly, neither firm is receiving a contract, but firm H would do strictly better by defecting to δ^* and reaching cooperation with F. ■

Proof of Proposition 5. Consider event LH. Firm 1, of type L, would never disclose more than δ^*[39] since this would yield negative profits even if it is awarded the contract. Firm 2, the H-type discloses $\delta^* + \varepsilon$ in order to win the partnership. Therefore, firm 1 chooses to not disclose, while firm 2 chooses to disclose $\delta^* + \varepsilon$ in equilibrium.

Next, consider event HL. Firm 2, now of type L, would never disclose more than δ^* since this would yield negative profits, even when the firm is awarded the contract. Note that firm 2 can never win a cooperation as long as firm 1 can reach the disclosure level $\delta^*$and win the cooperation with certainty. Given the new belief structure, firm 1 has no incentive to disclose either, since it receives the contract independent of disclosure, and $\delta = 0$. In equilibrium, neither firm discloses and F picks firm 1. ■

Proof of Proposition 6. Recall that the optimum disclosure level at which the firms separate was found at $R = C_f + c_L(\delta^*)$. Subsidies covering $S = C_f$ lead again to separation with $R = c_L(\delta^{**})$, $c_L(\delta^{**}) > c_L(\delta^*)$, and $\delta^{**} > \delta$.. This completes the proof.

[39]Note that the incentive structure follows case 1. Thus, δ^* solves $R = C_f - c_L(\delta^*)$.