Little Firms and Big Patents

International Patent Filing Incentives and Competition for Technology Partners

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Abstract

This paper considers a three-player signaling game to study patent filing strategies of small firms. In particular, filing incentives of two domestic firms that aim at attaining a partnership with a large foreign technology user are studied. Each firm's decision to file shall depend on the costs to reach a particular disclosure quality and on the payoffs that the foreign firm expects to receive from cooperation with the firm under consideration. Different payoff regimes are discussed. The disclosure level of known technology competitors and the profit expectations of the foreign partner are discussed in two separating/semi-separating profit regimes. In general, separation is reached. However, in one regime both firms have equal chances to win a partnership. Patent subsidizations that typically aim at reducing the costs of patent applications do not change the result. An empirical case in point is provided to motivate the analysis.

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1 Introduction

The enormous amount of patents annually applied for in the U.S. and Europe points us toward two important facts. First, innovation serves as a major catalyst for technological change and economic growth. Second, the value and the contribution of individual patents are quite varied.[1] The highly skewed nature of patent distributions may be explained by the fact that one obstacle for many inventions is that inventors are independently unable to market their inventions. The reason may include but is not limited to an inability to secure sufficient funding, a lack of complementary assets and a lack of access to innovation markets and to distribution channels.

Innovations are not necessarily created by the parties that are best able to exploit them and to appropriate their value. There are markets for innovation, mechanism that match inventors with parties that see the highest value of an invention. A mechanism commonly employed to disclose and communicate such inventions is international patent filing, such as filing outside the domestic patent system. Recent empirical studies[2] confirm that patent systems are an effective means for technology diffusion. Without doubt, the growing complexity of products and processes has increased technological collaboration and cooperation. In this context, patent systems serve to keep the division of labor working between internationally operating multi-technology enterprises and small high-tech firms. Schalk et al. (1999) report that in particular large and innovative firms use the patent literature to distill information about existing knowledge. Technology seekers typically limit their retrieval process to larger patent sources, they e.g. prefer the European patents statistics or EPO (European Patent Office) database to smaller sources. Technically advanced countries within the EU offer national patent systems with high quality standards. International firms see transaction costs, such as language barriers, as being too high to typically retrieve patent information from these smaller sources.[3]

[1] See Giummo (2006) and Harhoff et al. (2003).

[2] The OECD (2004) study describes patent systems as an effective means for technology diffusion, following the observation of an increased utility of information contained in patents. Similar aspects are highlighted in Schalk et al. (1999), Blind et al. (2003) and Legler et al. (2004).

[3] For smaller countries such disadvantages can be further exacerbated by the existence of additional costs. Much of the potential benefits that a "single market for patents" may generate in the EU follows this line of argument. Policymakers both favor the "community patent" and more generally aim at improving the quality of the patent

From a strategy perspective, how will small high-tech firms decide on filing for patent? Patenting is multi-faceted, and firms may follow different strategies when deciding on patenting in their home country versus abroad. Firms may primarily want to secure their intellectual property rights in their home country when filing domestically, but property rights are less of an issue when a technology is to be disclosed internationally in attracting new partners. Filing behavior of high-tech start-ups may be motivated by the international marketing effects that result from filing in larger patent systems. They may judge the risk of disclosing valuable information to possible competitors as being relatively low; their domestic position being secured through existing domestic patents. This difference in domestic versus foreign filing behavior holds in particular for firms in small countries; start-ups need partners to expand.

The information structure that arises naturally in such a context deserves particular attention. When two real senders exist, prior beliefs and payoffs are no longer independent. By offering a three-player model, this paper takes into account different disclosure levels of *actual* competitors when determining a firm's equilibrium filing strategy. New conclusions can be drawn in particular when innovation markets are of "high value", with the foreign partner firm expecting high profits from cooperation. The equilibrium construction with three players offers a rich and interesting treatment. It both permits me to investigate a firm's response to the domestic competitor's strategy, and to analyze the incentive compatibility conditions leading to separation or semi-separation in equilibrium. With one sender, such an extended analysis is not possible. Moreover, separation is facilitated with two actual senders, which corresponds to the findings of the prevailing literature on signaling.[4] The model considered here has little in common with "quasi burning-money" aspects that occur under dissipative signaling. Firms do not squander money in order to disclose whatever they can; rather, they encompass targeted disclosures to signal their quality to an international

system. One particular issue is the adoption of International Patent Classification Standards (EPO, 2006). The international marketing effect of patents and patent filings is of interest for niche firms, for firms in developing countries and those that aim at cooperations with firms in large markets nearby (EU member aspirants that aim at patenting in the EU, firms in Central America and Canada aiming at partnerships with U.S. firms and filing in the U.S., etc.).

[4]This property is common in the duopoly quality signaling literature. See e.g. Bagwell and Ramey (1991) and Fluet and Garella (2002).

partner, in full knowledge of their own costs and their domestic competitor's possible disclosure level. Typically, firms that cannot reach the domestic competitor's disclosure level decide to not file at all, and pooling does not occur in the two-sender model. [5]

While common in the quality-guaranteeing price literature, signaling models with two senders are rare in the field of patenting. The paper permits to see defensive patenting strategies and the creation of "patent thickets" as being already included in a firm's domestic patenting decision. However, it does not study these motives explicitly. Its primary focus is on the ability of patents to enable innovation markets and on the analysis of strategic disclosure. The theoretical framework that I offer adds a new view on the role of patent systems as complex mechanisms that disseminate information.[6]

The paper is organized as follows. Section 2 describes a theoretical model to capture signaling in a competitive environment with two senders and offers an analysis of the structure of beliefs when the two senders choose their disclosure levels endogenously. Section 3 discusses the impact of typical patent subsidies. Section 4 provides a review of the literature, both on signaling and on patenting. There is some evidence that firms do not disclose internationally at a comparable rate when being paired with technologically more advanced domestic competitors. Such an empirical case in point is offered in Section 5. Section 6 concludes.

2 The model

2.1 A leading example

Consider a start-up i in a particular country (henceforth labeled "domestic") that holds a domestic patent on some technology. Assume now that i considers expanding, with possibly interesting partners being located abroad. What are i's strategies? What makes it presume that its technology will find enough attention by F, a large technology user residing in a different country ("foreign"

[5] Newest contributions and extensions to the duopoly signaling literature (Daughety and Reinganum, 2005 and 2006) are close in spirit. Note that in my paper the costs of incremental innovation that each firm undertakes before filing are never observed by the foreign partner.

[6] Kahin (2003) has highlighted that patents may enable innovation markets and favor small firms. He adds a related argument, namely that other effects like the exposure to liability and open marketing may lead small firms to either "sell out or at least seek the protection afforded by large partners."

hereafter). If i's technology cannot be utilized by F, a disclosure through patent filing may not trigger any partnership, whatever the patent value of the domestic invention may be. It simply lacks technological opportunity for F.

Now let us bring a second domestic firm, labeled j, into the scene. j may also own a national patent on a similarly applicable but otherwise different technology. Should j offer a better adaptable solution, will F still be interested in an adaptation of i's invention? I assume F does not know either firm before skimming the patent source but that i and j are in complete knowledge of the possible value of each other's technology. Now, 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 are higher to be picked by F. Conversely, should firm i have lower incremental development costs to reach a disclosure level that attracts F, i may find it advantageous to file.

2.2 Disclosure levels, payoffs and prior beliefs

I assume that the two firms signal their receiver-dependent quality through filing a patent outside their home country in a patent database to which F has access to. The level of disclosure is $\delta \in [0, 1]$, which I normalize to 1 in the case the highest possible quality is disclosed. As a borderline case, I assume that a domestic firm choosing a disclosure level $\delta = 0$ does not incur any costs of incremental development, nor of the (fixed) costs through patent applications. Contingent on the observation of a disclosure pair (δ_1, δ_2) through skimming the patent literature, firm F updates its beliefs and chooses one firm with which to form a partnership.[7]

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 an R&D partnership with either firm. Then, firm i's revenue function can be defined as a function of F's choice:

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

[7]This view follows Cohen's (1995) concept of technological opportunity, which reflects the cost of achieving some normalized unit of technical advance.

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 possible that a firm files the identical patent internationally; each domestic firm however may translate its invention into an international patent application that may catch 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 quality level of disclosure, δ_i, and innovates by spending the type-dependent variable development costs $c_i(\delta_i)$. The firm pays the fixed patenting costs C_f when filing. In a two-type world we assume the type dependent variable costs c_L and c_H, which permits us to illustrate the cost function $C_i(\delta_i) = C_f + c_i(\delta_i)$ as a function of disclosure quality, illustrated in *Fig.* 1 below.

INSERT FIG. 1 HERE

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, I call $\mu^i(\delta_i, \delta_j)$ firm F's assessment that firm i, when disclosing δ_i, holds competencies that belong to type i. The quality of the knowledge stock of firms i and j are perfectly negatively correlated, with $\mu^i(\delta_i, \delta_j) = 1 - \mu^j(\delta_j, \delta_i)$.[8]

I keep the following notation for the rest of the paper, which simplifies the setting: The *actual* level of disclosure indeed differs, and the two types of firms may not really be of high and of low knowledge, but that F, given profitability expectations, sees both differently. As in Hertzendorf and Overgaard (2001), Nature flips a coin and creates the following two exclusive events:

- *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.

[8]See e.g. Hertzendorf and Overgaard (2001).

F holds prior beliefs such that event HL occurs with probability ν, and consequently that event LH occurs with probability $1-\nu$. This assumption captures a wide range of settings and comes without loss of generality. For example, the two domestic firms may be perfect technology partners for technology users other than F and thus may have very high levels of disclosure quality. Furthermore, the existence of two real senders permits to capture other than a trivial setting in which by definition only one firm can win the cooperation, and F's profits are defined accordingly.

Since I study a model with two *actual* technology competitors, the analysis depends crucially on the payoff situation of F and thus on the chances to be chosen as technology partner by F. In cases with high profit expectations it may be worth aiming at being picked randomly, while in other cases firm L can never win a cooperation. To analyze L's options in a broad setting that studies different equilibrium situations is at the center of the analysis.[9]

The following payoff rankings hold for firm F. Whenever denoting F's profits, the superscripts L and H indicate F's cooperation partners; N stands for non-cooperation:

$$\Pi_F^H > \Pi_F^N > \Pi_F^L.$$

Firm F's profits do not depend on the level of disclosure of either domestic firm but on the type of the firm with which it is cooperating. The foreign firm is strictly worse off when cooperating with L because the cost 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. Thus, by disclosing information, the domestic firm(s) mitigate the problem of asymmetric information. This, as referred to in the conclusion, adds a new perspective on patent systems as mechanisms of knowledge disclosure, even if patent systems may offer better chances to large firms.

[9]For this analysis I rule out additional strategic behavior that would make the setting less illustrative. I assume that F does not produce for the 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 directly produce for the foreign market, to compete with F after the R&D stage.

2.3 Timing

The timing of the game reads as follows:

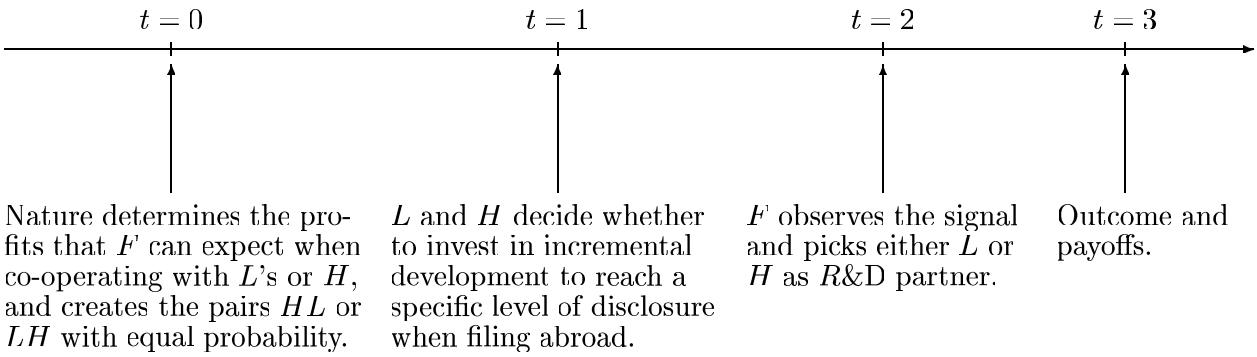

Fig. 2: Timing of the game

As mentioned above, decisions on domestic patenting are excluded in the game, but it is assumed that at $t = 0$ each domestic firm already holds a national patent that protects its intellectual property rights in its home country. This picture is realistic; it separates disclosure motives from patent rights and protection motives, thereby permitting a treatment of disclosure strategies. Incremental development reaches a possible quality increase for F, and through filing the domestic firms will disclose a technology that may typically not be a completely finished solution. The foreign partner, F, has the goal to pick the "better" domestic firm to form a cooperation.

2.4 Equilibria

The comparison of F's *ex-ante* payoff $\nu\Pi_F^H + (1-\nu)\Pi_F^L$ from cooperating with 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 of not cooperating, with $\nu\Pi_F^H + (1-\nu)\Pi_F^L \geq \Pi_F^N$. Cooperation is much more likely

in this situation. Under diffuse priors, 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 *A Perfect Bayesian Equilibrium (PBE) is a strategy profile* $(\hat{\delta}_H, \hat{\delta}_L)$ *together with a system of beliefs* μ *such that*

(i) $\hat{\delta}_H = \arg\max_{\delta_H} \Pi_H(\delta_H, \hat{\delta}_L; \gamma)$,
(ii) $\hat{\delta}_L = \arg\max_{\delta_L} \Pi_L(\delta_L, \hat{\delta}_H; \gamma)$,

and a system of beliefs such that consistency with strategies is fulfilled:

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

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

F's equilibrium strategy is

(v) $\hat{\gamma}(\delta_i, \delta_j) = i$ *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),

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

As a next step, I use the foreign firm's beliefs at out-of-equilibrium disclosures to find out which equilibria are supported by the out-of equilibrium beliefs.

First, I 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, since disclosure is costly and cannot influence F's decision. This equilibrium is trivial. It exists because of firm F's refusal to update. Thus, I henceforth 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) :

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

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

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, provided 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.

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

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

Case 1a: $\nu \geq .5$ [10]

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 why signaling is needed according to F's payoff condition $\nu\Pi_F^H + (1-\nu)\Pi_F^L < \Pi_F^N$ together with priors of $\nu \geq .5$. As shown in the solution below, F needs a separating signal to tell the two firms apart. Otherwise, cooperation remains impossible, based on the given belief structure.

Existence. I now analyze the conditions that induce the domestic firms to disclose these signals. Whenever speaking of the domestic firms' payoffs, we use the notation (δ_H, δ_L), in this sequence.

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

The superscript used for the domestic firms' payoff denotes the putative mode of cooperation, with C denoting 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 three IC constraints to hold, one for firm H,

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

and two for firm L:

$$\Pi_L^O(\delta^*, 0) \geq \Pi_L^N(\delta^*, \delta^*). \tag{IC L^N}$$

$$\Pi_L^O(\delta^*, 0) \geq \Pi_L^C(\delta^*, \delta^* + \varepsilon), \tag{IC L^C}$$

for any $\varepsilon > 0$.

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 plus 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), I 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.[11] 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: assume first 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, by sending such a signal would make F believe that its type is H, 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 firm F would 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

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

as long as firm F maintains the new belief structure. Since I limit the observation to equilibrium responses and to reasonable beliefs, should the separating PBE be a sensible prediction, I can drop the assumption that firm F will maintain any belief structure of this kind.

Thus, I have narrowed down the analysis 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 $R = C_f + c_L(\delta^*)$.

• 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 can exist given the existing belief structure.*

Proof. 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. ■

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

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

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

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

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

(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 $R \leq C_f + c_L(\delta^*)$.[12]

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.

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

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.

• **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^CP) rewrites into $.5R \geq C_f + c_H(\delta^*)$.

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

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. ■

Case 2b: $\nu > .5$

Changing the priors to $\nu > .5$ provides firm 1 with a natural advantage: F now chooses firm 1 whenever the two firms disclose the same amount, and the game also has equilibria under $\nu \Pi_F^H + (1 - \nu)\Pi_F^L \geq \Pi_F^N$. This leads to the general picture that firm 1 does not need to outbid firm 2; leveling up with H now becomes a sufficient strategy to be picked by F. As already stated in the introduction, the three-player analysis now delivers a lot of new insight: when can L level up with H?

Recall **Definition 2** on out-of-equilibrium beliefs. Using the same beliefs, we can now specify a particular δ^* in this case to be 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 LH and F awards the contract to firm 1.*

Proof. First, consider event LH. Firm 1, of type L, would never disclose more than δ^*[13] since

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

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 firm 1 is picked by F. ■

3 Subsidies

Within this setting I now ask which effect a subsidization of patent applications can have on the outcome. I restrict the analysis to feasible and observable forms of patent subsidies, namely to payments covering the filing expenses.

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

Proposition 6 *(Subsidization of filing costs cannot change the result when firms separate). Subsidies do not change the outcome of separating equilibria. Since there is no reason to assume that either domestic firm will keep its level of disclosure δ^* constant under subsidies, subsidies lead to wasteful competition in that both firms can now increase their level of disclosure.*

Proof. 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, per unit of increase, is less costly 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. 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 remains the same since the technologically more advanced firm H will again separate from L.[14]

The policy interpretation that follows is of some value. Covering the costs of filing cannot improve the disclosure quality. Public actors, who cannot or do not want to target particular firms with far-reaching subsidies, will not change the result. It is not surprising that less technologically advanced firms do not file in equilibrium, and that supply-side measures like subsidizations are not applied for in equilibrium by L.

4 Related literature

4.1 Signaling theory

The paper naturally fits into two strands of literature. The two-sender signaling model is close in spirit to recent contributions in the quality-guaranteeing price literature. Both Hertzendorf and Overgaard (2001) and Fluet and Garella (2002) use price-advertising disclosure pairs to signal product quality in a sequential game. Daughety and Reinganum's (2006) paper shares several properties with my model setup: product properties are defined similar to technology qualities in this paper. Both firms know one another's firm's quality, and only one variable (price in their model) is used to signal. In settings with enough vertical quality differentiation, one signaling variable is sufficient to reach separation. Such a situation arises naturally in my paper.

Hertzendorf and Overgaard (2002) analyze partial revelation using only price as disclosure variable in a two-sender model. Their paper is interesting for several reasons. It departs from the study of stable sequential equilibria, as modeled in Hertzendorf and Overgaard (2001) and Fluet and Garella (2002). Their refinement concept, based on Bagwell and Ramey's (1991) idea

[14] To change this outcome, government would not only need to ensure that only L would receive subsidies. 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, subsidies can incentivize L to disclose.

of unprejudiced beliefs, furthermore permits some interesting comparisons between monopoly and oligopoly cases. Finally, Caldieraro et al. (2006) in a two-stage signaling setting show a result similar to the present paper, namely that the low-quality firm discloses as well.

While this body of work has made an enormous leap from Nelson's (1974), Klein and Leffler's (1981) as well as Milgrom and Robert's (1986) seminal contributions on product quality and pricing[15], the signaling literature on patenting and disclosure is less unified. Horstmann et al.'s (1985) seminal contribution uses an innovating firm that is informed about a competitor's (follower's) payoff and decides on playing a mixed strategy between disclosing and not. Recent papers have shed a different light on the role of disclosure. Anton and Yao (2004) have stressed three particular features that determine disclosure strategies, in line with the management of intellectual property rights: incomplete information, limited protection, and enabling knowledge revealed through disclosure. Although the authors use a two-player model, my paper is similar in flavor to theirs. Their concept of "enabling knowledge" is based on an assumption that knowledge disclosed in a patent permits the receiver to infer the total knowledge that a firm possesses. In turn, my paper links quality to the necessary disclosure level determined through an actual third player, namely the domestic technology competitor. In a related paper, Anton and Yao (2003) have researched signaling capability and transferring knowledge in the presence of different regimes of intellectual property rights. In their own discussion on the similarities between the two bodies of literature, the authors offer additional comparisons between "enabling disclosure signals" in patenting and price or advertising choices in the quality-garanteeing price literature.

4.2 Patents as ex-ante co-ordination device

Another body of related work is the empirical literature on the informational aspects of patent filing. Wright's (1983) early contribution can be seen as the forerunner to an entire strand of literature to which this paper contributes in its broader sense. It traces back to the understanding that the patent system is a device for ex-ante co-ordination (Foray, 1995; Kitch, 1977; Machlup, 1958). Foray's (1995) view that patents do not only facilitate disclosure but that a patent system carries

[15]For an excellent overview see Riley (2001).

more tasks than usually illustrated in the patent race world, is a further stepping stone toward the informational treatment of disclosure incentives. My paper can be seen as a next contribution to the field of invention and disclosure incentives. In particular, Wright (1983, p. 691) has elaborated on the different incentives that patents, contracts, and prizes offer. His analysis of incentives and information compares the *relative merits* of such settings. Much of his argument relates to the problem that I have stressed above, namely that a public actor's decision may be of little value in the determination on how private actors handle and disclose information.

That firms patent for different reasons, and that disclosure in order to gain reputation may be one of them, have been recently confirmed by several studies. Blind et al. (2003) have offered a survey and have listed a ranking of patent motives. Three well-known and recent studies, namely Cohen et al. (2000), Schalk et al. (1999), as well as Blind et al. (2003) rank reputation and technical image as a motive for filing relatively high. Blind et al. (2003, p.79) furthermore mention that licensing together with patent exchange and positioning are seen as being of importance. Overall, the increasing internationalization of patents, in particular of small firms (OECD, 2004 and 2005) further illustrates the need for an informational treatment at the invididual level. Already Harabi (1995) has shown that small firms patent "as a means of entry into foreign markets" (Harabi, 1995, p. 990). This corresponds with the findings of recent empirical studies that include latent determinants of patenting behavior in their analysis. Reitzig (2004) has found that beyond visible determinants such as prices, costs, or sold quantities, latent determinants like novelty, inventive step, breadth, the difficulty of inventing around, disclosure, and dependence on complementary assets are important aspects of patent value. The present paper adds an informational perspective to the concept of latency.

This view is in particular backed by Faust's (1990) observation that patent applications in foreign countries may be determined by profit expectations that a firm under consideration may hold (e.g. following licensing)[16]. Only if the commercial value would compensate for the higher

[16]It should be mentioned that the idea of international patenting also relates to other entry modes into foreign countries. Fosfuri (2000) has compared technology licensing, exports and direct investment and found that innovators prefer licensing over the other forms in the absence of imitation.

costs, a firm may want to take international patenting into consideration. International patents are repeatedly seen by small firms as their stake for future R&D partnerships. Second, as to the importance of a domestic competitor, Kabla (1996) observes more generally that the propensity to patent depends on the patenting behavior of other firms operating in the same branch.

5 A case in point

Although the model extends to several settings, the following empirical case delivers a helpful illustration in form of a natural experiment: the case of East-German firms after Germany's re-unification. This case is of some interest because of the abrupt change that firms faced in an entire region. I have documented elsewhere the existence of a persistently low percentage of international patent filings over a long period of time, namely the one of East-German firms, compared to their West-German partners (Gick, 1998). This is illustrated in the graph below, which shows a particularly stark difference in foreign filing behavior between East-German and West-German firms after re-unification (see *Fig.3*):

INSERT FIG. 3 HERE

Fig.3 illustrates foreign patent filings of East-German and of West-German firms between 1991 and 1996, relative to their domestic filing activities. While East-German firms have increased their *domestic* patent position in a very short time and have reached levels similar to firms that were resident in the *representative* West-German region (Gick, 1998), the percentage of their international filings[17] compared to their domestic filings was strikingly low (below 25%), remaining at a low level for a long period of time. East-German firms' international filings also contrast with those of firms in other EU countries, where firms usually file about 45% of their domestic patents in a patent system outside their home country. This situation has remained stable for a long period of time, even in the presence of massive subsidies covering filing costs. The general picture has continued

[17]The data used in Gick (1998) followed the IFO patent statistics, which has been closed after 1998. This source included international patent filings at the EPO, US PTO and in Japan.

even after 1996, but it is less pronounced when applied to EU-wide filings only, as Legler et al. (2004) show.[18]

The argument that follows from the model in Section 2 is that technological quality is receiver-dependent. The abrupt change that Germany's re-unification imposed on East-German firms around 1990 has cut them off their technology base as well as their product markets, at the same time pairing them with strong competitors in Western Germany. While East-German firms were able to secure their domestic market in the unified Germany rather quickly, rates of filing abroad lack substantially. Because the high standards of the German Patent Office make it likely for a patent to attain EU protection, the reason was not a lower probability of being granted an EU-wide patent.[19] Instead, what made the East-German firm the L- firm over a long period of time was that its technology showed little promise for international partners.

6 Conclusion

It is well known that innovation requires more than just a good idea. Patents don't create markets, rather "it is the research and development of intelligent and marketable products"[20] which does. Having a valuable technology in one market does not imply having a foothold in a different one. Innovation markets work because firms are willing to disclose their technology, and large technology users skim the relevant patent literature.

The central argument of the paper is the following. Under realistic beliefs that firms hold about rival technology producers in their home country and about technology partners abroad, firms

[18] Legler et al. (2004), based on European and German patent data, have compared West-German and East-German patent applications at the German Patent Office (DPMA) and at the European Patent Office (EPA) in the years 1994-2001.

Relating EPA patent applications to domestic applications show that firms in Eastern Germany have increased their international (EU-wide) filing share after this period. This EPA to *domestic* application rate has reached 32% for East Germany versus 50% for West Germany in 1994, while in 2001 this ratio 55% in East Germany, and 59% in West Germany. One may conclude that after 1999 the gap between East and West Germany narrows. However, this does not take other international applications into account. The data in *Fig.* 3 contain patent applications outside the EU (U.S., Japan) and display the ratio of patent applications filed in more than one country to all patent applications.

[19] The comparably high quality standards required by the German patent office over the past decades suggests that the marginal patent is screened out (See e.g. Hall and Ziedonis, 2001, FN 22). This results in the high probability of German patents to reach international patent protection as well. I owe this thought to Mark Schankerman.

[20] Laudien (1995, p. 256).

indeed file for patents if their invention offers a sufficient degree of technological opportunity to the latter, compared to the quality that the domestic competitor can disclose. That is, firms use the patent system to reveal their knowledge. In a regime where the foreign partner expects low profits from a cooperation, the H-firm separates through disclosing in equilibrium. Conversely, in a richer setting that involves a relaxed payoff situation with the priors of F being skewed toward one firm, the situation is less competitive. My general result is that the two firms separate, and that pooling equilibria do not exist. More strikingly, the existence of semi-separating equilibria permits us to see the options of the two firms in a different light; high payoff expectations of the foreign partner ease the situation of the lagging domestic firm and give it a foot in the door.

The paper has extended the general result toward a realistic analysis of patent subsidies as an instrument for policymakers. I show that under reasonable assumptions on the policymaker's options, subsidizing patent applications will not change the result. This speaks in favor of a new understanding concerning the role of information and the usage of the patent system.

Patent systems are disclosure channels for those who need it, and they are of particular value. Hayek's (1945) well-known viewpoint to isolate "the problem of what is the best way of utilizing knowledge initially dispersed among all the people"[21] is a typical problem of the market for innovation, to which this paper has aimed to contribute. Firms know the "circumstances of time and place"[22] better than policymakers. Policymakers are not aware of what individual firms already know but do not tell. Even if a patent system may offer particular advantages to large enterprises, firms may still find it useful to disclose their knowledge internationally through patent filings.

The goal of my paper was to analyze the strategies and incentives that small firms face when disclosing through foreign patent filing, given particular profit expectations of the targeted foreign partner and the known technology position of a domestic competitor. Without doubt, the informational aspect of a patent system will remain an important topic for future research, and the present paper has shed some light on the issue. That firms reach semi-separating equilibria is a particular feature of two-sender model, and the payoff regimes are subdivided into cases in which the analyis

[21] Hayek (1945).
[22] Hayek (1945).

of different priors proves intuitive.

While capturing a range of relevant payoff regimes, my model leaves space for several extensions. To keep a balance between tractability and realism, I have limited the analysis to two larger scenarios and refrained from adding additional modeling options. Partnerships between small high-tech firms and large partners may encompass far more than a research cooperation. Moreover, once undertaken between the domestic start-up and the foreign partner, cooperations may influence domestic product market competition, which may change their strategic behavior. Such aspects are left for future research.

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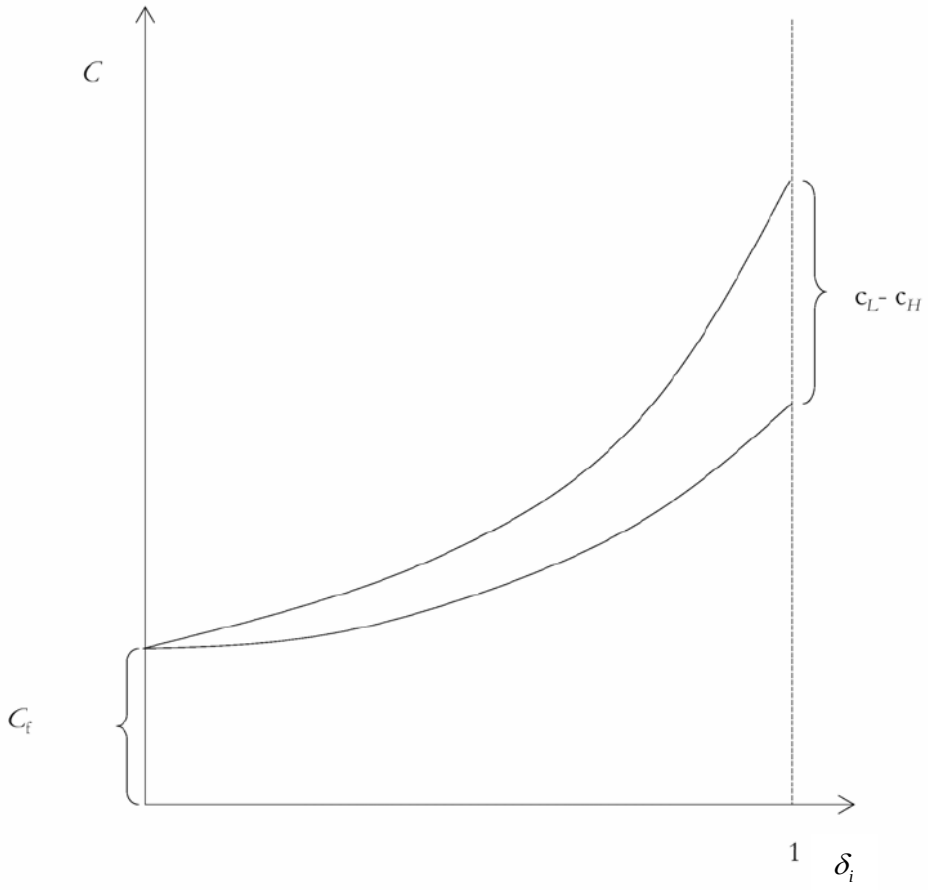

Fig.1

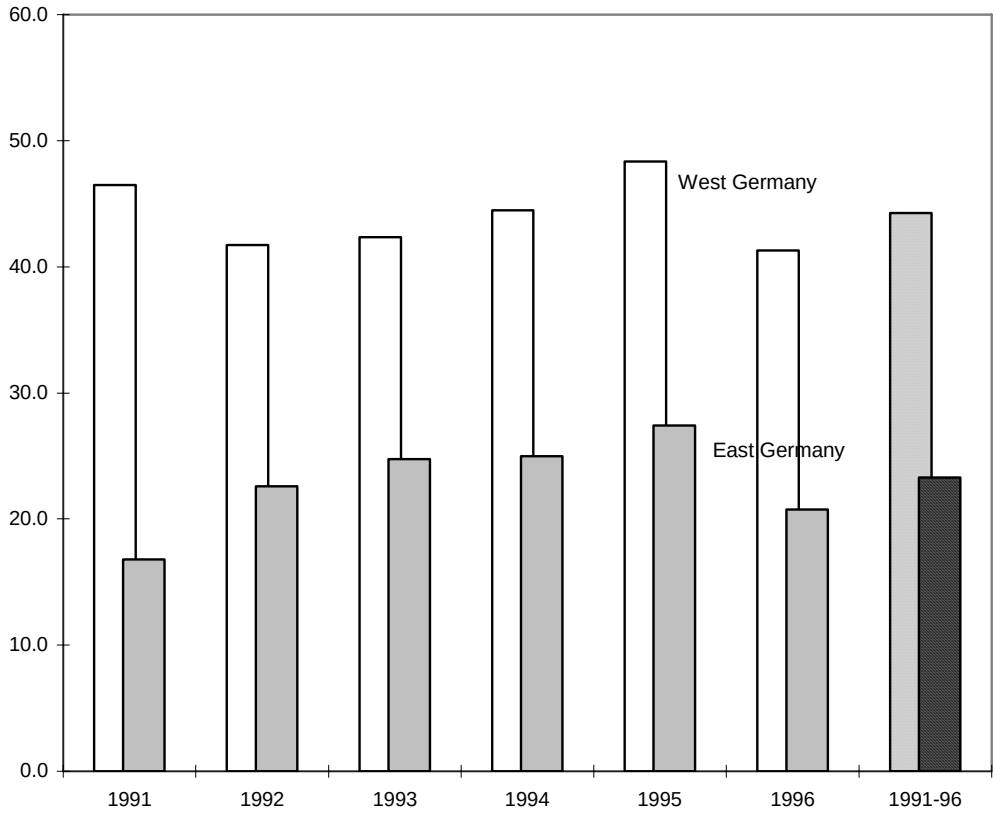

Fig. 3

Percentage of patent applications in at least two countries compared to national patent applications in West and East Germany. Source: Gick (1998). Data based on IFO patent statistics. The values for 1996 are without U.S. data.