UMR GAEL Laboratoire d'Economie Appliquée de Grenoble

DO BROAD PATENTS DETER RESEARCH COOPERATION ?

TROPEANO Jean Philippe ; TROMMETTER Michel

September 2009

JEL CODES : D23 ; 034 ; 031

KEYWORDS : INNOVATION ; SECRET ; PATENT, COOPERATION, KNOWLEDGE SHARING

Working Paper GAEL ; 2009-07

Institut National de la Recherche Agronomique - Université Pierre Mendès France
Unité Mixte de Recherche 1215
Domaine Universitaire - BP 47 - 38040 GRENOBLE Cedex 9
Tél. : 33 (0) 4 76 82 54 39 - Fax : 33 (0) 4 76 82 54 55
E-mail : vertier@grenoble.inra.fr - http://www.grenoble.inra.fr

Do broad patents deter research cooperation?

Michel Trommetter and Jean-Philippe Tropeano*

Abstract

We develop a theoretical model where two competing firms need access to basic knowledge that only one firm owns. We determine the impact of an imperfect property right on the incentive to transfer that knowledge to the competitor. We compare three transfer strategies. (i) patenting may lead to litigation costs that depend on the competition toughness. (ii) keeping the knowledge secret involves no licence revenue but ensures a monopoly profit. (iii) The firm can also cooperate with the competitor and thereby avoids litigation. We show that whenver competition between both firms is low, making patentable basic knowledge promotes knowledge transfer through research cooperation.

*GAEL, UMR INRA-Université Pierre Mendès France de Grenoble. E-mail: michel@inra.grenoble.fr and tropeanj@upmf-grenoble.fr.

1 Introduction

One of the main objectives of a patent is to promote knowledge transfer. Yet, the patent may lead to transaction costs that hinder the efficiency of knowledge transfer. Let us consider for instance a typical example such as the one of Myriad Genetics. In 2001, the European Patent Office (EPO) granted to this biotech firm a patent for the first genetic test detecting predisposition to breast cancer in which two genes, BRCA1 and BRCA2, play a key role. The patent was granted for any test implying one of these two genes. Myriad decided to use of that very broad patent to preserve its monopoly position by denying any type of licence to competing tests. As a response, competitors decided either to ignore Myriad's patent or to launch an opposition procedure (see Gold and Carbone, 2008). Eventually, in November 2008, Myriad won European patent appeal but the scope of its patent has been drastically reduced since the revised patent claims are no longer over both genes. In order to avoid the litigation costs and possible patent scope reductions, Myriad could have decided, instead, to cooperate with other potential users by giving them open access to the basic knowledge (namely the two genes) with a research cost sharing agreement. For example, the Single Nucleotid Polymorphysm (SNP) consortium consists for the members to finance over 300,000 human SNPs and to make them freely available after obtaining provisional patents (Williamson, 2000) to avoid litigation.

Such examples lead some practitioners and researchers (Henry et al., 2003 or Roffe, 2007) to conclude that a cooperative solution combines incentives to innovate with open access to basic knowledge and therefore is more efficient, from a social point of view, than a broad patent that leads to costly access to knowledge due to high licence fees and litigation costs. As a result, they recommend to prohibit patent for very basic innovations. However, in the absence of broad patents, firms might keep their knowledge secret. Therefore, a broad patent may lead to better (although costly) access to knowledge. Yet it might induce firms to cooperate less than in the case where broad patents are not available. According to a study by Ménière et al. (2008) based on 35 interviews with French public laboratories, this solution is increasingly frequent. 20 laboratories out of 35 have recourse to the secrecy to manage the conditions of access to collections of genetic material and data basis.

We ask in this paper: *does a broad patent deter firms to carry-out a cooperative solution to transfer knowledge?* Our objective is thus to examine, from a theoretical point of view, *the impact of patent prohibition for basic innovations on the incentive to cooperate to share basic knowledge.*

Our main result shows that having the option to patent basic innovations is likely to promote knowledge sharing through research cooperation.

Plant breeding is an appropriate example to illustrate the three main options a firm considers regarding knowledge transfer.

Consider a new plant variety that entails a particular characteristic such as pathogen's resistance or gustatory quality. The access to the genetic marker of the sequence which codes the innovating characteristic could lead a competitor to use that characteristic in a different plant variety. The initial innovator has three main options regarding the genetic marker. First, he can keep it secret. Second, he can patent it with or without granting a licence to its competitor. Third, the innovator can propose to the competitor to cooperate by sharing research cost with open access to the genetic marker. We aim at determining the incentive to cooperate with the competitor if the genetic marker is patentable.

Let us present our framework and the underlying mechanisms of our results. We consider a firm, the "innovator", that owns a basic innovation. That firm as well as a "competitor" could use the basic innovation to carry-out two different applications. The innovator faces three main options regarding the transfer of the basic innovation: patenting, research cooperation or secrecy. We present briefly each solution.

First, if the innovator patents the basic innovation, the induced knowledge disclosure allows the competitor to develop its application. The innovator requires a licence from the competitor. Nevertheless, the competitor can refuse the licence contract arguing that its innovation does not infringe the patent due to substantial differences between the basic innovation and the application. In this case, the innovator may sue the competitor. The outcome of the trial is uncertain and depends among other elements on the characteristics of the application (Merges and Nelson, 1994). We assume here that the probability for the patent holder to win the trial does not depend on the quality of the patent. We focus only on the possible infringement of the competitor's application on the original patent. For this reason, we consider that the patent holder is less informed than the competitor on the probability of actual infringement. For instance, in the Myriad case, it was hard for Myriad to anticipate the eventual decision of the European Patent Office that depended eventually, among other things, on the characteristics of the alleged infringing innovation (Gold and Carbone, 2008). As a result of the information asymmetry, the patentee and the competitor can fail to settle on a licence agreement. Therefore, patenting involves possible litigation costs.

Second, the firm can propose research cooperation to the competitor. Research cooperation consists in sharing the basic innovation, so that both firms have open access to the basic innovation, provided that the competitor accepts to pay a fixed fee defined by the innovator. Thus the fixed fee is an access price to the basic innovation. It worth noting that two main features justify the term cooperation. First, the fixed fee leads to cost sharing between both firms and second both firms have open access to the basic innovation.

Third, the firm can keep the innovation secret and thus denies the access to the other innovator. We consider here an extreme situation since we assume that in case of secrecy the competitor cannot develop its own innovation. Therefore, if the firm keeps the basic innovation secret, it enjoys monopoly power.

According to our first result, in the absence of a patent for the basic innovation, if both firms provide sufficiently different applications of the basic innovation, cooperation is the most profitable solution for the innovator since it allows the innovator to benefit from knowledge sharing through the access price required to the competitor. Put it differently, the firm prefers the cooperative solution for low levels of competition on the market. For high level of competition, the basic innovation is kept secret.

The introduction of possibility to patent basic innovations modifies substantially this trade-off between competition and the access price.

The patent accommodates competition through the royalty rate of the licence contract. Thus, if the licence contract is accepted, the patent is the solution that leads to the highest level of total profit to be shared between both firms. Yet, licence refusal by the competitor triggers costly litigation. We show that competition toughness plays a key role in the competitor's decision to refuse the licence contract. Indeed, if the competitor accepts the licence contract he must pay the royalty rate as well as the fixed fee. Nevertheless, the royalty rate softens competition between both firms on the market for applications. If the competitor decides to refuse the licence contract, at best he wins the trial and avoids any licence fee but faces tougher competition. We deduce that the higher the competition on the market for application, the higher the opportunity cost for the competitor to dispute the patent. Therefore, the benefit of the patent increases with competition.

Eventually, the innovator prefers research cooperation whenever competition is soft and chooses the patent otherwise. Two main reasons explain that optimal choice according to the level of competition. In case of tough competition, the competitor is willing to accept the licence contract to avoid costly litigation and competition on the market implied by research cooperation leads to low level of profit. Instead, as far as competition is soft, the competitor is more reluctant to accept a licence and thus, the innovator is induced to prefer research cooperation to avoid litigation and moreover soft competition does not reduce so much the profit of both firms. Nevertheless, cooperation is chosen against the patent for higher levels of competition than against the secret.

More importantly, we show that the patent is not always preferred to the research cooperation solution. Rather, the opportunity to patent the innovation is likely to foster cooperation. Indeed, the possibility for the firm to patent the basic innovation increases the bargaining power when it negotiates the access price in case of research cooperation. *In fine,* the basic innovator could prefer to cooperate rather than to file a patent in order to avoid costly litigation even for competition levels where the secret was more profitable than cooperation.

Here is our most important result. *We stress that the introduction of the patent is likely to encourage cooperation rather than to deter the cooperative solution to transfer knowledge.* Indeed, even if the broad patent is available, the firm may still prefer the cooperation in order to avoid litigation costs. We usually oppose research cooperation and intellectual property right such as the patent. Rather, we show here that both could complement each other. We stress that *the patent could facilitate open access to knowledge through the cooperation.*

We can also interpret our cooperative solution as an "open licence", that is a licence that makes available the knowledge under the payment of a lump-sum fee (generally free). Indeed, most of the time, under the open licence, the licensor's innovation remains patented in order to restrict the open licence to specific uses of the innovation. For example, in the Eco-Patent Commons initiative, IBM associated with Nokia, Sony and Pitney Bowes give open and free access to a large number of innovations but for research and development in the field of sustainable development only. As an expert of the sector explains : "it is important to understand that these groups do not give up these patents". In that way, if they assume that third parties innovations competed with them on their own sector, they could always withdraw the licence. This example illustrates our theoretical result where the patent complements the open access granted to the innovation.

The related literature

To our knowledge, our paper is the first to analyze the trade-off between secrecy, cooperation and the patent.

Nevertheless, a large literature studies the sole role of either the patent or research cooperation on knowledge transfer between firms.

A stream of the literature examines the trade-off between patent and secrecy either between competitors (among others, Anton and Yao, 2004, Kultti and Takalo, 2005) or on a vertical structure (Battacharya and Guriev, 2006). Our main contribution to this literature is the introduction of research cooperation as a third alternative.

Other models focus (Green and Scotchmer, 1995 or d'Aspremont et al., 2000) on the optimal way to induce knowledge transfer between two firms.

Green and Scotchmer (1995) examine the role of the patent breadth on the incentive to innovate of an upstream innovator and an application (a downstream innovator). They argue that as long as licences could be negotiated before research costs are incurred, the broad patent granted to the basic innovation gives the right incentives to both innovators. Indeed, the broad patent constrains the downstream innovator to negotiate a licence with the upstream innovator. Moreover, since both innovators negotiate ex-ante, an agreement always exists. This is close to our result on the complementarity between the broad patent and research cooperation but for a very different reason. Indeed, they assume a very strong patent so that the basic innovator can always constrain the downstream innovator to negotiate a licence. Instead, in our model, it is the presence of litigation costs that leads the upstream innovator to prefer the cooperative solution. Thus, in brief, in Green and Scotchmer it is the very strong patent that induces both firms to agree ex-ante whereas in our model it is the "weakness" of the patent that leads the upstream innovator to share knowledge ex-ante.

d'Aspremont et al. (2000) study a licence contract between an "informed firm" that could be induced to transfer knowledge to a competitor. They show that there exists an incentive compatible and individually rational contract that leads to full disclosure. Unlike their model, we consider two different ways for firms to share knowledge: the patent associated with a licence contract and "cooperation" which is a lump-sum monetary transfer that gives open access to knowledge to the competitor. Moreover, in their paper, the cooperation or knowledge sharing is always profitable since it leads to a total profit increase. Rather, our two solutions involve private inefficiencies with respect to the maximized total profit. We study the in that framework the incentive to share knowledge as well as the most profitable solution to do so.

In our model, the patent involves possible litigation costs because of both the probabilistic nature of the patent and asymmetric information. The first models that study the role of probabilistic patents on litigation are Farrel and Shapiro (2008 and 2005) and Meurer (1994). The patent part of our model is very close to Llobet (2003). Nevertheless, we introduce in this type of model the cooperative solution as a competing solution for the innovator to sell knowledge to a competitor.

2 The model

We first present the framework and then we give details on the timing of the game.

2.1 The framework

We consider two firms: an "upstream innovator", denoted by I, and a "downstream firm" denoted by E. Firm I owns a basic innovation and can develop an application from that basic innovation. The downstream firm does not know the basic innovation and thus is unable to carry-out any application alone. Nevertheless, once the basic innovation is displayed, firm E is able to develop its own application.

Both applications are imperfect substitutes. We denote by the parameter γ the toughness of competition between both firms: the higher γ, the higher the competitive pressure. We develop an Hotelling framework in the appendix where $\frac{1}{\gamma}$ is the degree of differentiation between both applications. We assume that the downstream innovations (the applications) are patented.

The upstream innovator can adopt three basic strategies regarding the basic innovation. Let us present briefly these strategies.

Research cooperation

Firm I proposes to the downstream firm to share knowledge at price F. Once firm I proposes to firm E to share knowledge, the firm reveals the existence of the basic innovation. If firm E accepts, firm E has full access to the basic knowledge and thus develops its application with probability 1. Both firms compete on the market for applications and thus the profit earned by each one is a duopoly profit denoted by $\pi^d(\gamma)$. We assume that the higher competition on the market, the lower the profit $\pi^d(\gamma)$. If firm E refuses the price F proposed by firm I, firm E is able to develop the application with probability δ only (with $\delta \in [0, 1]$). Firm E earns an expected profit equal to $\delta\pi^d(\gamma)$ and the expected profit of firm I is equal to $\delta\pi^d(\gamma) + (1 - \delta)\pi^m(\gamma)$ where $\pi^m(\gamma)$ is the monopoly profit earned by firm I when firm E does not innovate. This strategy is denominated as "cooperation" since both firms share the upstream innovation and the price F leads to research cost sharing. We can also interpret this cooperative solution as an "open licence". There are huge disparities in the open source world. Nevertheless, there are open licences without any restriction in the use of knowledge. It is the case of the BSD licence. In such a case the open licence amounts to a lump-sum payment for open access to knowledge.

The secrecy

The firm keeps its basic knowledge secret. In that case we assume full secrecy so that the downstream entrant has no access to the basic innovation and thus cannot develop its application (it amounts to assume $\delta = 0$). Therefore, I is the only firm to develop an application and thus enjoys the monopoly profit denoted by $\pi^m(\gamma)$.

The Patent

The upstream innovator patents the basic innovation. Knowledge disclosure allows the downstream firm to develop its own application (it amounts here to consider $\delta = 1$). Nevertheless the patent holder, firm I, can require a licence from firm E. The licence contract is a two-part tariff with a royalty rate, r, and a fixed part P. If firm E accepts the licence contract, the profit of each firm depends on the royalty rate denoted by r. Hence the profit of both firms: $\pi^{I,d}(r,\gamma) + P$ for firm I and $\pi^{E,d}(r,\gamma) - P$ for firm E. There exists a royalty rate that maximizes the joint profit $\pi^{I,d}(r,\gamma) + \pi^{E,d}(r,\gamma)$. We denote by r^* such a royalty rate and the corresponding joint profit is equal to $\Pi(\gamma)$.

The application of firm E is likely to infringe on the patent. The probability of infringement depends on the technical characteristics of the application. The higher the technological proximity between the basic innovation and its application, the higher the probability of infringement. More specifically we denote by x the probability a Court considers there is patent infringement. The upstream innovator does not observe x and has only prior beliefs on x given by the uniform distribution on the interval $[\underline{x}, \overline{x}]$. The dispersion as well as the average of the distribution depend on the range of claims of the patent. If the upstream innovator decides to sue firm E for infringement in case of disagreement on the licence contract, both firms incur a cost C. When the court considers the application actually infringes on the patent, firm I has the opportunity to renegotiate the licence contract. Otherwise there is no licence and firms compete on the market for applications. Whenever both firms compete without any licence agreement, the profits earned are thus $\pi^d(\gamma)$ and $\pi^d(\gamma)$. In a general framework, the probability x would depend on the different technical characteristics of the application of firm E. Therefore x should be positively correlated with parameter γ. We consider here first that the interval is independent from the parameter γ so that firm I cannot infer the expected probability of infringement from the observation of γ. At the end of the paper we discuss the case where parameter γ provides information on the distribution of x.

We denote the total welfare with one application by W^S, with two applications and a royalty rate equal to r by $W^P(r)$ and finally with two applications that compete on the market without any royalty rate by W^C. We assume that total welfare are ranked as follows: $W^S < W^P(r) \leq W^C$ because two applications improve total welfare with respect to one application only and because the royalty rate r introduces a distortion.

2.2 The game

We consider two different configurations in terms of intellectual property rights for the basic innovation. In the first configuration, the usefulness requirement of the patent office is soft and thus the upstream innovation can be patented. In that case we say that a "broad patent" is granted and the timing of the game is the following (see also figure 1):

1. The upstream innovator chooses its strategy regarding the basic innovation:

(i) The firm keeps the basic innovation secret.

(ii) The firm patents the basic innovation

(iii) The firm proposes to firm E to share the basic innovation at a cost F (research cooperation).

2. If firm E refuses the access price F, firm I can patent the basic innovation.

3. If the innovation is patented, firm I proposes a licence contract (P, r)

4. If firm E refuses the licence contract, firms go to trial[1]

5. Both firms compete on the market for applications.

In the second configuration, the patent office requires direct application for an innovation to be patented and thus the basic innovation cannot be patented. Here the timing of the game is the same as before without the patent solution.

Moreover, firm E observes the probability x when firm I patents the innovation.

Our main objective is to determine the effect of the patent for the basic innovation on the choice between the secret and research cooperation. For that purpose, we study first the benchmark case where the basic innovation cannot be patented. Then, we introduce a patent for the basic innovation so as to point-out its role on the incentive of the upstream innovator to share knowledge through the cooperative solution.

3 Research cooperation versus secret without patent

In the absence of patent for the basic innovation, firm I can either keep the basic innovation secret or propose research cooperation to firm E.

The strategy adopted by the upstream innovator is summarized in the following proposition.

[1] We consider that if firm E refuses the licence contract, firm I decides to go to trial. We show that this is actually the case a far as C is not too high.

Proposition 1 *In the absence of patent for the basic innovation, there exists a threshold $\gamma^{np}(\delta)$ such that the upstream innovator chooses to keep the basic innovation secret as long as $\gamma > \gamma^{np}(\delta)$ and cooperate with firm E otherwise.*

In order to understand the choice between cooperation and secrecy, we should determine the profit earned by the upstream innovator in both configurations.

If firm I decides to cooperate with firm E, both firms compete on the market for applications. Moreover, because of the absence of patent to exclude firm E from the use of the basic innovation, firm E accepts to pay at most $(1-\delta)\pi^d(\gamma)$ to cooperate. Otherwise, firm E would prefer to try to develop the application by itself. The profit of firm I is then $(1-\delta)\pi^d(\gamma)+\delta\pi^m(\gamma)$.

The secret ensures a monopoly profit but firm I does benefit from the profit of the other potential application.

Clearly, the higher the competition, the lower the profit earned in case of research cooperation because of a lower duopoly profit. Hence the critical level of competition $\gamma^{np}(\delta)$ above which the firm prefers the secret. We should note that high probabilities for firm E to develop the basic innovation alone reduce the price firm I can impose to the downstream firm to cooperate. This is why the threshold of parameter γ depends on δ.

This result should be considered as the benchmark case where the absence of patent leads the innovator to use the secret as long as competition is high enough. This configuration is the starting point to study to what extent the patent is likely to affect the incentives to share the basic innovation with firm E.

4 Research cooperation or patent?

We consider now that a patent protection is available for the basic innovation. We aim at determining whether the upstream innovator will actually patent the basic innovation, keep it secret or propose cooperation to the other firm.

We assess first the expected profit following the patenting of the basic innovation. Then we determine the profits induced by research cooperation so as to determine the optimal strategy.

4.1 Patent, litigation cost and optimal licensing

The patent does not guarantee a licence revenue for firm I since firm E can claim that its own application does not infringe on the patent and thus can refuse the licence contract. Moreover, since the patent holder does not observe the full characteristics of the application, firm I is unable to perfectly know the probability with which a court will consider that the application of firm E actually infringes the patent.

We investigate the optimal licence contract proposed by firm I to firm E. Because of information asymmetry regarding the probability of infringement, the licence contract proposed by firm I plays as a screening device. The following lemma provides the different outcomes following the basic innovation patenting and the optimal licence contract proposed by firm I.

Lemma 1 *At the equilibrium, there exists a threshold $\widehat{x}(\gamma)$ such that the licence contract proposed by firm I is accepted by firm E iff its type x is larger than $\widehat{x}(\gamma)$. Moreover, the threshold $\widehat{x}(\gamma)$ decreases with γ and there exists a value of γ above which $\widehat{x}(\gamma) = \underline{x}$.*

We show in this lemma that whenever firm E has a probability to win a trial for infringement high enough (higher than the threshold $\widehat{x}(\gamma)$), she refuses the licence contract and both firms go to trial. If we denote by $q(\gamma)$ the probability of conflict, we have $q(\gamma) = \int_{\underline{x}}^{\widehat{x}(\gamma)} \frac{1}{\overline{x}-\underline{x}} dx$. Not surprisingly, the information asymmetry on the probability of infringement induces potential conflict between both firms. More specifically, we show in that lemma that the risk of conflict depends dramatically on the level of competition on the market for applications. Tough competition reduces the risk of litigation. Let us disentangle the impact of asymmetric information on the licence contract proposed by firm I and the reason why a high level of competition induces firm E to accept the licence contract.

In the absence of any informational asymmetry, both firms can avoid costly litigation by designing the licence contract accordingly. The royalty rate is set at r^* to maximize the joint profit and the fixed fee allows the firms to divide $(\pi^I(r^*, \gamma) + \pi^E(r^*, \gamma) = \Pi(\gamma))$ in order to avoid litigation. Thus, the level of the fixed part would depend mainly on the probability of success of firm E in case of trial. In other words, both firms would avoid litigation costs and would share the monopoly profit, $\Pi(\gamma)$, according to the probability of dependence x.

Asymmetric information on the parameter x prevents to implement such a strategy and affects the profit sharing as well as the rate of dispute between both firms.

The licence contract still consists of a royalty rate that allows the maximization of the joint profits. Yet, information asymmetry modifies the level of the fixed part. Firm I faces the following trade-off in setting the fixed fee, P. If the firm increases P, it leads to a higher litigation rate but also rises the licence revenue while a lower fixed fee reduces the licence revenue but decreases the risk of litigation. The optimal level of P depends on the choice of firm E. The refusal of the licence contract allows the firm not to pay a licence fee with probability x which is private value. Nevertheless, the refusal involves also two different costs: the firm incurs the litigation cost and the level of competition results higher because of the absence of the softening effect of the royalty rate. Hence the higher the competitive pressure on the market, the higher the cost to refuse the license contract and therefore the higher the incentive to accept this licence contract. This is the reason why the rate of approval of the licence contract increases with the competitive toughness γ. We show that if the level of competition is high enough, the licence contract is always accepted and thus the firms never go to trial.

Once the optimal level of the licence contract is determined, we can deduce the expected profit of both firms. We denote by $\Pi^{E,b}(\gamma, C)$ the profit earned by firm E and by $\Pi^{I,b}(\gamma, C)$ the profit of firm I. The following lemma provides both profits.

Lemma 2 *If firm I patents the basic innovation, the whole expected profit of both firms is equal to:* $\Pi^{E,b}(\gamma, C) + \Pi^{I,b}(\gamma, C) = \Pi(\gamma) - (1 - Q(\gamma))(\Pi(\gamma) - 2\pi^d(\gamma)) - (1 - q(\gamma))2C$
where $Q(\gamma)$ *is the probability firm* E *pays a licence to firm* I*.*

We stress that both firms fail to share the maximized joint profit $\Pi(\gamma)$ whenever there is a positive probability of conflict. This result will turn-out to be crucial in the trade-off between patent and cooperation.

We capture in this lemma the inefficiency of the patent. In lemma 1, we showed that both firms cannot avoid costly litigation and in case of litigation, the inefficiency is twofold. First, both firms earn the duopoly profit rather than $\Pi(\gamma)$ whenever there is no licensing. Hence the term $(\Pi(\gamma) - 2\pi^d(\gamma))$. Second, firms incur litigation costs captured by the term $(1 - q(\gamma))2C$.

The level of both inefficiencies depends critically on the probability with which firm E refuses the licence contract (probability $1-q(\gamma)$) as well as on the probability with which firm I looses the trial. Overall, the probability $Q(\gamma)$ gives the probability with which there is a licence contract. It is the case as far as either firm E accepts the licence contract proposed by I or looses the trial.

In lemma 1 we stressed that the probability of trial depends critically on the level of competition. As a result, the lower the competition, the higher the probability the licence contract is refused. Thus, if competition is tough on the market for applications, most of the time both firms agree on a licence contract. The total profit is then equal to $\Pi(\gamma)$ and the patent avoids profit inefficiency. If competition is soft, an agreement would require a low fixed part. Firm I

prefers to keep the fixed part at a level that could lead to trial. Hence a higher probability of disagreement and thus possible profit inefficiency and litigation costs.

In other terms, soft competition compounds the impact of asymmetric information on the innovation characteristics of firm E and by reducing the chance of agreement. Instead, the toughness of competition lowers the patent inefficiencies.

In the next section, we turn to compare the expected benefit of the two other research strategies, namely the research cooperation and the secret, with the patent outcome.

4.2 Patent versus research cooperation

Firm I can decide to keep the innovation secret or to propose to firm E research cooperation rather than to patent the basic innovation. The following proposition provides the optimal choice.

Proposition 2 *The choice between patent, research cooperation and secret gives rise to the following decision rule:*

There exists a threshold of the competition toughness γ^p such that for any $\gamma > \gamma^p$, the firm I patents the basic innovation while for any $\gamma < \gamma^p$, both firms cooperate.

The choice of the best strategy for firm I is the result of a trade-off between the costs and benefits of each solution. Basically, research cooperation does not incur any litigation costs but leads both firms to compete on the market for applications. If firm I patents the basic innovation, litigation costs reduce the profit but softens competition. The secrecy preserves the monopoly profit but firm E does not enter and thus firm I does not earn revenue from from access to its basic innovation.

Let us explain the outcome of this trade-off.

First we should note that here the patent solution always dominates the secret. Consider for instance a licence contract where firm E obtains the duopoly profit. Firm E accepts such a contract since in case of trial, the firm cannot obtain more than the duopoly profit. The profit earned by firm I is thus equal to $\Pi(\gamma) - \pi^d(\gamma)$. We show that this contract ensures at least the profit under secrecy which is equal to the monopoly profit for one application only ($\pi^m(\gamma)$). In other words, firm I always prefers patenting and licencing the basic innovation to firm E rather than to keep it secret. In that sense the patent we consider in that model is a powerful instrument to induce knowledge transfer. This result relies on two main assumptions.

First, knowledge transfer gives rise to a second application that increases the value of the basic innovation since the profit $\Pi(\gamma)$ is always higher than the monopoly profit for the application of firm I only ($\pi^m(\gamma)$). Second, the unconstrained licence contract used by firm I allows the firm to share the monopoly profit $\Pi(\gamma)$ between both firms.

Therefore, the choice for the firm I amounts to compare patenting with research cooperation as the most profitable choice to transfer knowledge. It worth stressing here that even though the patent is a very profitable instrument to transfer knowledge, according to proposition 2, cooperation could be preferred by firm I.

This choice between research cooperation and patent gives rise to the following trade-off. On the one hand, cooperation avoids any litigation cost. Nevertheless, since both firms have access to the basic innovation, no licence contract is required to firm E and thus both firms compete on the market. In addition to the duopoly profit, firm I earns the price paid by firm E. This price depends on the expected profit of firm E if the firm refuses to cooperate and if afterwards firm I patents the basic innovation. On the other hand , the patent is likely to constrain firm E to accept a licence contract in order to sell its own application. That licence contract increases the profit of firm I through the licence revenue itself as well as through the accommodating impact of the royalty rate on competition. Notwithstanding, if firm E refuses the contract proposed, firm I incurs a litigation cost. Thus the comparison between the patent and research cooperation amounts to compare the expected litigation cost that reduces the profit efficiency of the patent with the toughness of competition on the final market that affects the profit earned under cooperation.

In lemma 1, we stressed that the probability of litigation decreases with the competitive pressure γ. Hence the threshold γ^p of the level of competition above which firm I prefers the patent solution. In other words, a high level of competition deters research cooperation for two main reasons. First, the patent avoids tough competition thanks to the royalty rate that softens competition. Second, tough competition deters firm E to go to the trial and thus increases the efficiency of the patent system by reducing the risk of litigation. It is important to note that the level of competition does not matter only for the research cooperation profit but also for the patent solution profit through the risk of litigation. Assume instead that the patent is free of any litigation cost. In that case, because the joint profit $\Pi(\gamma)$ is always higher than the duopoly profit $2\pi^d(\gamma)$, the patent would always dominate research cooperation even for very low level of competition. Thus it is the presence of of litigation costs magnified by soft competition that lead the innovator to prefer research cooperation.

In order to determine to what extent the introduction of the patent for the upstream innovation undermines cooperation we must compare the thresholds $\gamma^{np}(\delta)$ and γ^{p}.

It is easy to show that for $\delta = 1$, we have $\gamma^{p} > \gamma^{np}(1) = 0$. In that case, the patent does not deter research cooperation. Rather, the patent promotes the knowledge transfer through cooperation since for the range of γ equal to $[0, \gamma^{p}]$, the patent allows research cooperation whereas without patent firm I prefers the secrecy. Nevertheless, there exist lower values of δ where γ^{p} is lower than $\gamma^{np}(\delta)$ (see the appendix). In that case the patent deters cooperation as the knowledge transfer solution.

Let us explain why the patent is likely to be preferred to the cooperative solution for low values of δ and why the patent is likely to support the cooperative solution for higher values of δ.

Consider first the case where the parameter δ is high. The introduction of the patent increases the expected profit of firm I whenever firm E refuses to cooperate. This higher profit is due to a better protection of the basic innovation with patenting that allows firm I to capture a higher share of the profit of firm E. Therefore, when firm I negotiates the access price in case of cooperation, the patent is a threat that increases its bargaining power. Thus the patent allows firm I to increase the price of cooperation. Nevertheless the patent involves a risk of litigation that is costly for firm I. As a result the firm uses the patent as a bargaining instrument but in the end can prefer cooperation in order to avoid any litigation cost. This is the reason why the introduction of the patent is likely to promote the cooperative solution as far as litigation costs remain high.

If firm E has a low probability to innovate if it refuses to cooperate, the bargaining power of firm I is high even without patent. It is the case whenever δ is low. Here, the cooperation prevails against the secrecy without the patent even for high level of competition. For such high levels of competition, the litigation rate is low so that the patent solution increases the profit with respect to the cooperation. The patent deters cooperation as a result.

The effect of the introduction of the patent on the welfare is ambiguous as well, at least for low values of δ. Whenever the cooperative solution is adopted without the patent and is replaced by the patent, there is a welfare loss since $W(r) < W^{c}$. Nevertheless, the patent also increases the welfare by both avoiding the secret and promoting the cooperative solution for high values of δ. Yet, it worth noting that for high values of δ, the introduction of the patent is always welfare improving since in that case the patent always supports cooperation.

Our model allows to study the role of litigation costs on the actual litigation rate as well as on the trade-off between patent and research cooperation. An increase in the litigation cost reduces the litigation rate. A higher C induces both firms to avoid litigation. Nevertheless the impact on the cooperative solution is ambiguous. Indeed, research cooperation is enhanced by high expected litigation costs and the impact of a higher C on total litigation costs is unclear since an increase in C rises the cost in case of trial but also lowers the probability to go to trial.

If we follow our open licence interpretation of cooperation, according to proposition 2, our predictions are twofold. First, the downstream innovator uses the open licence solution to avoid litigation costs. Moreover, the upstream innovator grants such a licence for downstream innovations that are sufficiently different from its own application only. Otherwise firm I prefers the patent solution.

At the equilibrium, the litigation rate depends directly on the expected probability for firm I to win the trial. We examine in the following proposition the impact of both a change in the average probability as well as in the dispersion of probabilities on the litigation rate $q(\gamma)$.

Proposition 3 *At the equilibrium, the litigation rate increases with both the average and the dispersion of the distribution of the probability (x) for the patent to be infringed by the competitor (firm E).*

We argue that an increase in both the average probability for firm I to win the trial as well as a higher dispersion induce more litigation. Indeed, both changes in the distribution of the probability x lead to higher levels of the probability to win the trial. Firm I takes advantage of such higher probabilities to set a higher licence fee that leads to a higher litigation rate.

We can interpret a higher average probability as a broader patent in terms of range of claims. In that case, a broader patent promotes the cooperative solution since a broader patent increases the litigation cost and thus induces the firm to choose the cooperation.

This proposition also allows to study the case where the observed characteristics of the application of firm E captured by the parameter γ, provides information on the probability x. We consider the following relationship between the interval of x and the parameter γ. First, we assume that the closer both applications, the higher the average probability for firm I to win the trial because of dependence. Second, regarding the dispersion of the probability, we can consider an inverted-U shape relationship so that for very close or for very different applications, the dispersion of probabilities is low whereas for an intermediate value of the parameter γ, the dispersion is higher. We can determine to what extent this type of correlation between the characteristic of the application and the probability of dependence modifies the trade-off between the patent and the cooperative solution.

If we start with very close applications, the high level of competition leads both firms to avoid litigation in case of patent. Thus, despite the high average probability of dependence that is likely to increase the litigation rate, the patent solution dominates.

If we focus on intermediate values of γ and more particularly on the threshold γ^p, two effects go in opposite directions. The higher level of dispersion due to the intermediate value of γ tends to increases litigation and thus favors the cooperative solution. Nevertheless the lower probability of dependence is likely to reduce litigation. As a result, it is unclear whether the threshold is positively or negatively affected by the information provided by the correlation between γ and the distribution of x.

If we consider very different applications, the very low level of competition leads to a high litigation rate despite the low dispersion of the dependence probability. The optimal choice remains cooperation, as a result.

5 Conclusion

We develop in this paper a framework to analyze the choice between secrecy, intellectual property right and cooperation. We consider a firm that can use of a basic innovation to develop an application. The basic innovation can also leads another firm to develop a different application. We first determine the incentives for the basic innovator to either cooperate with the competitor to give him access to the basic innovation or to keep the basic innovation secret. Then, we contrast the emergence of cooperation with and without patent for the basic innovation. We stress the dramatic role played by the patent by showing that cooperation emerges if the company that owns the basic innovation has the option to protect it by an intellectual property right. In that sense, we argue that intellectual property rights could be crucial to promote cooperation. More precisely, we show that without patent, secrecy tends to dominate cooperation whereas the introduction of the patent promotes cooperation as long as competition on the market for applications remains soft and the strength of the patent is low enough.

In terms of intellectual property right public policy, we conclude that if a country does not make patentable the basic innovation, such a decision could be harmful to cooperation and thereby to expected social welfare by triggering secrecy. Nevertheless, a too strong intellectual property right -high probability of wining counterfeit lawsuit - could also be harmful to cooperation.

6 Appendix

Proof of proposition 1

Firm I proposes a price F to cooperate. If E accepts, its profit is equal to $\pi^d(0,\delta) - F$. If E does not accept its expected profit is $\delta\pi^d(\gamma)$.

Thus firm I can require a price $F = (1-\delta)\pi^d(0,\delta)$.

Under the secret, firm I earns $\pi^m(\gamma)$. Hence the threshold $\gamma^{np}(\delta)$ is the solution of $\pi^m(\gamma) = (2-\delta)\pi^d(\gamma)$.

Proof of lemma 1 and lemma 2

1. We determine first the licence contract proposed by firm I at the equilibrium.

Firm I proposes a contract (r, P) to E

(i) Behaviour of firm E of type x

Firm E accepts the licence (r, P) iff $x > \widehat{x}$ with $\widehat{x}$ is the probability that leads firm E to indiffrent between accepting the licence and refusing it. We have $\widehat{x}$ such that:

$$\begin{aligned} \pi^{E,d}(r,\gamma) - P &= (1-\widehat{x})\pi^d(\gamma) - C \\ iff\ \widehat{x}(P,r) &= \frac{\pi^d(\gamma) + P - C - \pi^{E,d}(r,\gamma)}{\pi^d(\gamma)} \end{aligned}$$

For extreme values of P, we have:

$\widehat{x}(P,r) = \underline{x}$ iff $P < \underline{P} = Max(0, \pi^{E,d}(r,\gamma) - (1-\underline{x})\pi^d(\gamma) + C)$

$\widehat{x}(P,r) = \overline{x}$ iff $P > Max(0, \pi^{E,d}(r,\gamma) - (1-\overline{x})\pi^d(\gamma) + C) = \overline{P}$

(ii) Determination of the optimal licence contract (P, r)

First, firm I determines the royalty rate r.

We first show that firm I sets the royalty r at a level that maximizes the total profit of both firms given by $\pi^{I,d}(r,\gamma) + \pi^{E,d}(r,\gamma)$. Let us denote by r^* such a royalty.

Indeed, consider instead a contract (r, P) with $r \neq r^*$.

We can find P' such that:

$\pi^{E,d}(r^*,\gamma) - P' = \pi^{E,d}(r,\gamma) - P$ and such that $\pi^{I,d}(r^*,\gamma) + P' > \pi^{I,d}(r,\gamma) + P$

since we have:

$\pi^{I,d}(r^*,\gamma) + P' = \pi^{I,d}(r^*,\gamma) + \pi^{E,d}(r^*,\gamma) - \pi^{E,d}(r,\gamma) + P > \pi^{I,d}(r,\gamma) + \pi^{E,d}(r,\gamma) - \pi^{E,d}(r,\gamma) + P$

Thus without affecting the gain of firm E, the royalty r^* is better than any level r.

We denote by $\Pi(\gamma) = \pi^{I,d}(r^*, \gamma) + \pi^{E,d}(r^*, \gamma)$.

Second, firm I determines P that maximizes the expected gain.

If E accepts the licence $(x > \widehat{x})$, I earns $\pi^{I,d}(r, \gamma) + P$

If E refuses $(x < \widehat{x})$, I earns $(1 - x)\pi^d + x\Pi(\gamma) - C$

Thus the expected profit of firm I is equal to:

$[1 - F(\widehat{x}(P)] \left[\pi^{I,d}(r^*, \gamma) + P - \pi^d(\gamma) + C\right] + \left[\int_{\underline{x}}^{\widehat{x}(P)} xf(x)(\Pi(\gamma) - \pi^d(\gamma))\right] + \pi^d(\gamma) - C$

The derivative of the expected profit with respect to P gives:

$$[1 - F(\widehat{x}(P))] - f(\widehat{x}(P))\widehat{x}'(P) \left[-\widehat{x}(\Pi(\gamma) - \pi^d(\gamma)) + \pi^{I,d}(r^*, \gamma) + P - \pi^d(\gamma) + C\right]$$

If we replace P by its expression, we have also:

$$[1 - F(\widehat{x})] - f(\widehat{x}) \left[(1 - \widehat{x})\frac{\Pi(\gamma) - 2\pi^d(\gamma)}{\pi^d(\gamma)} + \frac{2C}{\pi^d(\gamma)}\right]$$

for an uniform distribution this is equal to:

$$\frac{1}{\overline{x} - \underline{x}} \left([\overline{x} - \widehat{x}] - \left[(1 - \widehat{x})\frac{\Pi(\gamma) - 2\pi^d(\gamma)}{\pi^d(\gamma)} + \frac{2C}{\pi^d(\gamma)}\right]\right)$$

Let us study this derivative with respect to $\widehat{x}$.

We can define: $G(\gamma, \widehat{x}) = \left[(1 - \widehat{x})\frac{\Pi(\gamma)-2\pi^d(\gamma)}{\pi^d(\gamma)} + \frac{2C}{\pi^d(\gamma)}\right]$ and $H(\widehat{x}) = \overline{x} - \widehat{x}$.

We have $H'(\widehat{x}) = -1$ and $\frac{\partial G(\gamma,\widehat{x})}{\partial \widehat{x}} = -\frac{\Pi(\gamma)-2\pi^d(\gamma)}{\pi^d(\gamma)}$

Therefore, we have $H'(\widehat{x}) > \frac{\partial G(\gamma,\widehat{x})}{\partial \widehat{x}}$ iff $\Pi(\gamma) > 3\pi^d(\gamma)$ iff $\gamma > \widetilde{\gamma}$.

Moreover, for $x = \overline{x}$, we have $H(\overline{x}) - G(\gamma, \overline{x}) = 0 - \left[(1 - \overline{x})\frac{\Pi(\gamma)-2\pi^d(\gamma)}{\pi^d(\gamma)} + \frac{2C}{\pi^d(\gamma)}\right] < 0$

Therefore, if $\gamma > \widetilde{\gamma}$, the derivative is always negative (it is increasing and negative for $x = \overline{x}$) so that $\widehat{x} = \underline{x}$.

For $\gamma < \widetilde{\gamma}$, we have $H'(\widehat{x}) < \frac{\partial G(\gamma,\widehat{x})}{\partial \widehat{x}}$ which makes possible an interior solution.

In that case we must evaluate $H(\underline{x}) - G(\gamma, \underline{x})$.

We have $H(\underline{x}) - G(\gamma, \underline{x}) = \frac{1}{\overline{x}-\underline{x}} \left([\overline{x} - \underline{x}] - \left[(1 - \underline{x})\frac{\Pi(\gamma)-2\pi^d(\gamma)}{\pi^d(\gamma)} + \frac{2C}{\pi^d(\gamma)}\right]\right)$.

If $\gamma = 0$, we have $H(\underline{x}) - G(\gamma, \underline{x}) = \frac{1}{\overline{x}-\underline{x}} \left([\overline{x} - \underline{x}] - \left[\frac{2C}{\pi^d(0)}\right]\right)$ and thus for C low enough the difference is positive. Therefore, there exists an optimal $\widehat{x}$ that equalizes the derivative to 0 $(H(\widehat{x}) - G(\gamma, \widehat{x}) = 0)$ with $\underline{x} < \widehat{x} < \overline{x}$.

Let us study the impact of γ on the optimal solution $\widehat{x}$.

For an interior solution ($\underline{x} < \widehat{x} < \overline{x}$), we have $\widehat{x}$ uniquely defined by $H(\widehat{x}) - G(\gamma, \widehat{x}) = 0$.

Thus we deduce that:

$$\frac{d\widehat{x}}{d\gamma} = -\frac{\frac{\partial G}{\partial \gamma}}{\frac{\partial G}{\partial \widehat{x}} - \frac{\partial H}{\partial \widehat{x}}} < 0$$

since $\frac{\partial G}{\partial \gamma} > 0$ and $\frac{\partial G}{\partial \widehat{x}} - \frac{\partial H}{\partial \widehat{x}} > 0$

As a result, the optimal solution $\widehat{x}(\gamma)$ decreases with γ.

We deduce that there exits a unique threshold of γ above which $\widehat{x}(\gamma) = \underline{x}$ and below which $\overline{x} > \widehat{x}(\gamma) > \underline{x}$.

By assumption, we consider that firm I always decides to go to trial. It is profitable as long as the expected profit is positive which is the case if:

$\left[\frac{\int_{\underline{x}}^{\widehat{x}(P)} xf(x)}{F}\Pi(\gamma) - C\right] \geq \pi^d(\gamma)$. If C is low enough, the inequality holds.

2. Conclusion on payoffs and probability of litigation at the equilibrium

At the equilibrium, the expected profit for both firms are the following:

firm $I : \Pi^{I,b}(C,\gamma) = \int_{\underline{x}}^{\widehat{x}} \left(x\pi^d(\gamma) + x\Pi(\gamma)\right) f(x)dx + (1 - F(\widehat{x})) \left[\Pi(\gamma) - (1-\widehat{x})\pi^d(\gamma) + C\right]$

firm $E : \Pi^{E,b}(C,\gamma) = \int_{\underline{x}}^{\widehat{x}} (1-x)\pi^d(\gamma) f(x)dx + (1 - F(\widehat{x})) \left[(1-\widehat{x})\pi^d(\gamma) - C\right]$

We deduce the sum of both profits:

$\Pi^{E,b}(C,\gamma) + \Pi^{I,b}(C,\gamma) = Q(\gamma).\Pi(\gamma) + (1 - Q(\gamma))2\pi^d(\gamma) - q(\gamma)2C$

with $Q(\gamma) = 1 - F(\widehat{x}) + \int_{\underline{x}}^{\widehat{x}} xf(x)dx$. In other terms $Q(\gamma)$ is the probability with which a licence contract is implemented (after or before trial)

with $q(\gamma) = 1 - F(\widehat{x})$, the probability of trial. This probability decreases with γ since $\widehat{x}$ decreases with γ.

Proof of proposition 2

(i) Patent against secrecy

The patent always dominates the secret. Indeed, if firm E refuses the licence contract, she obtains at most $\pi^d(\gamma) - C$. Therefore, if firm I leaves E with $\pi^d(\gamma) - C$, it will always accept. In that case the profit of firm I is $\Pi(\gamma) - (\pi^d(\gamma) - C)$. In other terms, the patent ensures at least a profit equal to $\Pi(\gamma) - (\pi^d(\gamma) - C)$. In case of secret, the profit is $\pi^m(\gamma)$. We show in the appendix dedicated to our example that $\Pi(\gamma) = \pi^m(\gamma) + \pi^d(\gamma)$. Hence the domination of the patent over the secret.

(ii) Comparison between patent and cooperation

If firm I proposes cooperation to firm E, the price proposed is equal to:

$F = \pi^d(\gamma) - \Pi^{E,b}(C,\gamma)$ and thus firm I obtains $2\pi^d(\gamma) - \Pi^{E,b}(C,\gamma)$

As a result, cooperation is preferred as long as $2\pi^d(\gamma) > \Pi^{E,b}(C,\gamma) + \Pi^{I,b}(C,\gamma)$

We have: $\Pi^{E,b}(C,\gamma) + \Pi^{I,b}(C,\gamma) - 2\pi^d(\gamma) = Q(\gamma).(\Pi(\gamma) - 2\pi^d(\gamma)) - q(\gamma)2C$. We showed that $q(\gamma)$ decreases with γ and $Q(\gamma)$ increases with γ. Moreover the difference $\Pi(\gamma) - 2\pi^d(\gamma)$ increases with γ.

For extreme values of γ we have:

$\gamma = 0$: we have $Q(\gamma).(\Pi(\gamma) - 2\pi^d(\gamma)) - q(\gamma)2C = -2q(\gamma)C < 0$:cooperation is thus preferred

$\gamma = \widetilde{\gamma}$: we have $Q(\gamma).(\Pi(\gamma) - 2\pi^d(\gamma)) = Q(\gamma)\Pi(\gamma) > 0$: the patent is thus preferred

We deduce that there exists a unique threshold γ^p such that for any $\gamma > \gamma^p$, the patent solution is preferred and for any $\gamma < \gamma^p$, the cooperation solution is preferred.

(iii) Comparison of both thresholds γ^p and $\gamma^{np}(\delta)$.

The function $\gamma^{np}(\delta)$ decreases with δ and for $\delta = 0$, we have $\gamma^{np}(0) = 0 < \gamma^p$.

Let us show that we have in the Hotelling model $\gamma^p < \gamma^{np}(1)$.

We have $\gamma^{np}(1)$ such that $\pi^m(\gamma) = 2\pi^d(\gamma)$. Moreover we have $\Pi(\gamma) - \pi^m(\gamma) = \pi^d(\gamma)$.

Therefore for $\gamma = \gamma^{np}$, we have also $\Pi(\gamma^{np}) = 3\pi^d(\gamma^{np})$.

We showed in the proof of lemma 1 that if $\Pi(\gamma^{np}) = 3\pi^d(\gamma^{np})$, we have $\widehat{x}(\gamma) = \underline{x}$. In other terms there is no conflict and thus the patent solution is better than the cooperative solution for firm I.

We deduce that $\gamma^p < \gamma^{np}(1)$.

Proof of proposition 3

We start from the implicit expression of $\widehat{x}$ given by the following equation:

$$\left[(1-\widehat{x})\frac{\Pi - 2\pi^d(\gamma)}{\pi^d(\gamma)} + 2C\right] = \overline{x} - \widehat{x}$$

(i) An increase in the average probability $\frac{\overline{x}+\underline{x}}{2}$ leads to an increase in $\overline{x}$. It leads to an increase in $\widehat{x}$ and thus to a decrease in $\overline{x} - \widehat{x}$. It results a higher litigation rate since $\frac{\widehat{x}-\underline{x}}{\overline{x}-\underline{x}}$ increases.

(ii) An increase in the dispersion $(\overline{x} - \underline{x})$ with unchanged average probability.

It leads to an increase in leads to an increase in $\overline{x}$ and thus to a decrease in $\overline{x} - \widehat{x}$. Moreover we have $\frac{\widehat{x}-\underline{x}}{\overline{x}-\underline{x}} + \frac{\overline{x}-\widehat{x}}{\overline{x}-\underline{x}} = 1$. Since $\frac{\overline{x}-\widehat{x}}{\overline{x}-\underline{x}}$ decreases, the litigation rate, $\frac{\widehat{x}-\underline{x}}{\overline{x}-\underline{x}}$, increases.

A model of market competition between both applications

We consider a Hotelling differentiation framework where consumers are uniformly distributed on a segment $[0,1]$ according to the density function 1. Application I is located in 0 and application E is located in 1. We assume that both firms price discriminate between consumers. If we denote by $p_j(y)$ the price of firm j $(j = E, I)$ for a consumer located in y, this consumer earns a surplus equal to $V - p_j(y) - t\,|y-d|$ where t is a parameter that captures differentiation between both applications ($t > 0$) and d is the location of firm j ($d = 0$ for firm I and 1 for firm E).

We determine: (1) the profit of firm I when she is the only firm on the market, (2) the equilibrium when firm E pays a royalty rate r per unit and compete with firm I and (3) the royalty rate that maximizes the joint profit.

(1) Monopoly profit $\pi^m(\gamma)$:

The optimal price is equal to: $p_I(y) = V - ty$

Hence the monopoly profit $\pi^m(\gamma) = \begin{cases} V - \frac{t}{2} \text{ if } \frac{V}{t} > 1 \\ \frac{1}{2}\frac{V^2}{t} \text{ if } \frac{V}{t} < 1 \end{cases}$

(2) Competition with royalty rate

Since we consider that firms can perfectly price-discriminate, we also consider that the royalty rate depends on the location of each consumer. We denote by $r(y)$ such a rate for a consumer located in y. Moreover, because of perfect price-discrimination, there is price competition between both firms for each location. We consider the price equilibrium for each consumer located in y

(a) For $y > \frac{1}{2}$:

Let us determine the optimal response of firm I for a price $p_E(y)$

if $p_E(y) \leq V - t(1-y)$:

The optimal response of I is equal to:

$p_E(y) - (2y-1)\,t - \varepsilon$ if $p_E(y) - (2y-1)\,t > r(y)$ and higher than $p_E(y) - (2y-1)t$ otherwise where ε is as small as we want.

if $p_E(y) > V - t(1-y)$,

The optimal response of I is equal to $V - ty$

If firm I sets a price $p_I(y)$, the optimal response of E is:

$Max(p_I(y) + (2y-1)t; r(y))$ if $p_I(y) < V - ty$ and $Max(V - t(1-y)t; r(y))$ otherwise

Thus, the price-equilibrium for consumer y is:

$p_E(y) = r(y) + (2y-1)t + \varepsilon$ and $p_I(y) = r(y)$ if $r(y) \leq V - ty$

The total profit is equal to: $r(y) + (2y-1)t + \varepsilon$

$p_E(y) = Max(V - t(1-y); r(y))$ if $r(y) > V - ty$ and $p_I(y) = V - ty$

The total profit is equal to:

$V - (1-y)t$ if $r(y) < V - (1-y)t$

$V - yt$ if $r(y) > V - (1-y)t$

(b) For $y < \frac{1}{2}$:
Following the same reasoning, we have at the equilibrium:
$p_E(y) = r(y)$ and $p_I(y) = Min(r(y) + t(1 - 2y); V - ty)$
The total profit is equal to $Min(r(y) + t(1 - 2y); V - ty)$
(3) The optimal royalty rate $r(y)$ and the duopoly profit for $r(y) = 0$:
The royalty rate that maximizes the total profit is $r^*(y) = V - (1 - y)t$
We deduce:

$$\Pi(\gamma) = \begin{cases} V - \frac{t}{4} \text{ if } V > \frac{t}{2} \\ \frac{V}{t} \text{ if } V < \frac{t}{2} \end{cases}$$

The duopoly profit is:

$$\pi^d(\gamma) = \begin{cases} \frac{t}{4} \text{ if } V > t \\ \frac{1}{4t}\left(-2V^2 + 4Vt - t^2\right) \text{ if } \frac{t}{2} < V < t \\ \frac{1}{2}\frac{V}{t} \text{ if } V < \frac{t}{2} \end{cases}$$

As a result, we have always $\Pi(\gamma) - \pi^d(\gamma) = \pi^m(\gamma)$

References

[1] Anton and Yao (2004)- “Little patents and big secrets: managing intellectual property”, *Rand Journal of Economics*, vol. 35, page 1

[2] d’Aspremont, C., Bhattacharya, S and L-A Gérard Varet, 2000, "Bargaining and Sharing Innovative Knowledge", *Review of Economic Studies*

[3] Bhattacharya, S. and S. Guriev (2006), "Patents vs Trade Screts: Knowledge licencing and spillover", *Journal of The European Economic Association*

[4] Green, J. and S. Scotchmer (1995), "On the Division of Profit in Sequential Innovation", *Rand Journal of Economics*

[5] Farrell, J. and C. Shapiro (2008), "How Strong are Weak Patents", *American Economic Review*

[6] Kulti, K and T. Takalo, (2005), "Secrecy versus Patenting", miméo

[7] Llobet, G., (2003), "Patent Litigation when innovation is cumulative", *International Journal of Industrial Organization*

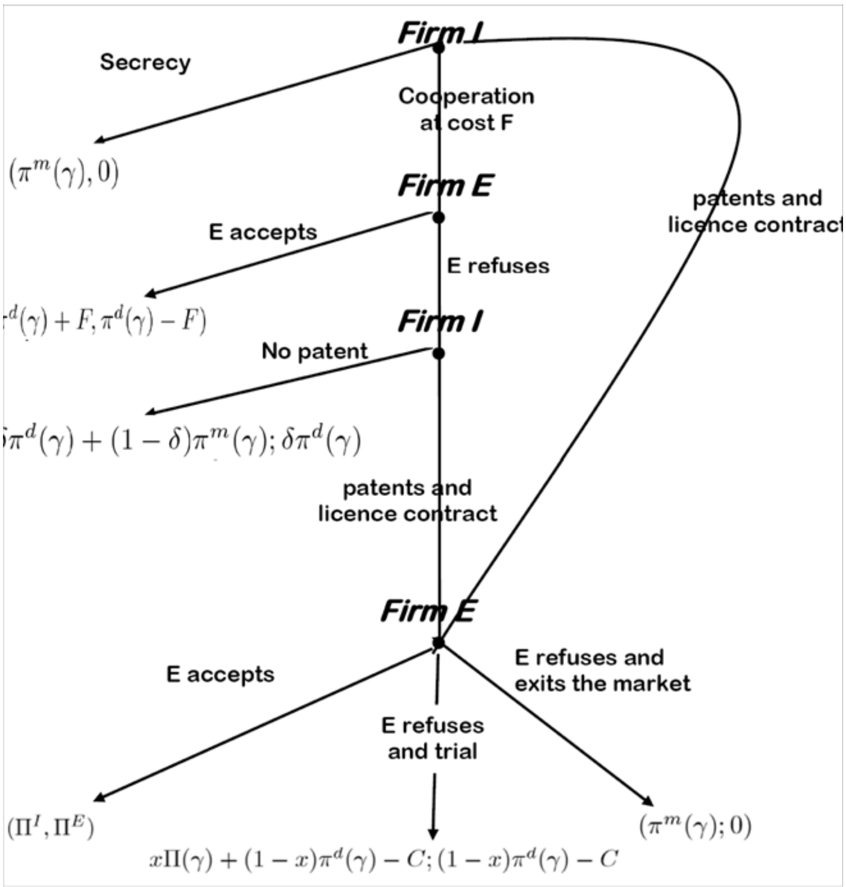
[8] Merges, R. and R. Nelson, "On the Complex Economics of Patent Scope", *Columbia Law Review*

[9] Trommetter M. (2005) - “Biodiversity and international stakes: A question of access”, Ecological Economics, vol 53, pages 573

[10] Trommetter M. (2007).- “Intellectual property right in agricultural and agro-food biotechnologies at horizon 2030”, OECD report, 25 Pages, work in progress.

[11] Williamson A. R. (2000).- “Creating a structural genomic consortium”, Nature structural genomics, supplement, pp. 953.

Figure 1



Firm I
Secrecy
Cooperation
at cost F
$(\pi^m(\gamma), 0)$
Firm E
patents and
licence contract
E accepts
E refuses
$\pi^d(\gamma) + F, \pi^d(\gamma) - F)$
Firm I
No patent
$\delta\pi^d(\gamma) + (1-\delta)\pi^m(\gamma); \delta\pi^d(\gamma)$
patents and
licence contract
Firm E
E accepts
E refuses and
exits the market
E refuses
and trial
(Π^I, Π^E)
$(\pi^m(\gamma); 0)$
$x\Pi(\gamma) + (1-x)\pi^d(\gamma) - C; (1-x)\pi^d(\gamma) - C$