Do patents deter open access?

Michel Trommetter*
Jean-Philippe Tropeano†

We develop a theoretical framework to analyze the choice between secrecy, patent and open access. We consider a firm that can use a basic innovation to develop an application. The basic innovation can also lead another firm to develop a different application. We determine the incentives for the basic innovator to give open access to the basic innovation or to keep it secret. We show that open access emerges more often if the company that owns the basic innovation has the option to protect it by a patent.

Patent Litigation – Licensing – Patent Design

Le brevet est-il l'ennemi du libre accès ?

Nous développons un cadre théorique pour analyser le choix entre le secret, le brevet et l'accès libre. On considère une firme qui peut utiliser une innovation de base pour développer une application. Cette innovation peut également être utilisée par une autre entreprise pour développer une application différente. On recherche les incitations pour l'innovateur initial de laisser son innovation de base en accès libre ou de la protéger par le secret. On montre que des situations d'accès libre apparaissent plus souvent si l'innovateur de base a également l'option de protéger son innovation par le brevet.

Brevet – Litiges – Open access – Licence

Classification JEL : D82, K11, O34

1. Introduction

In most of countries, the patentability of "basic innovations"[1] gives rise to a sharp debate. Those in favor of such patents stress that they make knowledge transfer easier (Green and Scotchmer [1995] for the main theoretical argument). Yet, the patent is an imperfect property right and thus often involves huge litigation costs that lower the efficiency of knowledge transfer as illustrated by the Myriad Genetics case. In 2001, the European Patent Office (EPO) granted to this biotech firm a patent for the first genetic test

* GAEL, UMR INRA-Université Pierre Mendès France de Grenoble. E-mail: michel@grenoble.inra.fr
† Université de Paris 1-Paris School of Economics. E-mail: tropeano@univ-paris1.fr

1. Innovations that lead to many different applications. We follow here the definition of Scotchmer [2005] page 132.

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 used that patent with very broad breadth to preserve its monopoly position by denying any type of licence to competing tests at a "reasonable" fare. As a response, competitors decided either to ignore Myriad's patents or to launch an opposition procedure (see Gold and Carbone [2010]). Eventually, 7 years later, Myriad won European patent office appeal but the scope (breadth) of its patent has been drastically reduced. In June 2013, the Supreme Court of the United States also greatly reduced the scope of the Myriad Genetics patents[2]. At the very beginning, to avoid litigation costs, Myriad could have decided, instead, to negotiate with the other potential users giving them open access to the basic knowledge (namely the two genes) at a lump-sum access fee (paid open access[3]). Paid open access could be defined as a contract which both stipulates an access fee to knowledge and guarantees that all of the future uses of that knowledge are free of royalty charge. The firm Celera Genomics used this kind of *ex ante* paid open access agreement for its human genome database[4]. Some practitioners and researchers (Henry *et al.* [2003]) argue that a prohibition of patent on living organism (particularly on DNA) would force firms to adopt this kind of paid open access solution that combines incentives to innovate with easier access to basic knowledge. However, in the absence of a patent system for basic innovations, firms might keep them secret.

Hence the main question we ask in this paper: does a patent deter firms to use *ex ante* paid open access 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 share basic knowledge. We show that having the option to patent basic innovations is likely to promote knowledge sharing through paid open access. Indeed, even if the patent is available, the firm may still prefer the paid open access to avoid litigation costs. We usually contrast paid open access with patent. Rather, we show here that both could complement each other since in the model, the patent could facilitate open access to knowledge through the paid open access solution.

To our knowledge, our paper is the first to analyze the trade-off between secrecy, paid open access and the patent. A large literature studies the sole role of either the patent or paid open access 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], Aoki and Hu [1999]) or on a vertical structure (Battacharya and Guriev [2006]). Other models (Green and Scotchmer [1995] or d'Aspremont *et al.* [2000], Erkal [2005]) focus on the optimal way to induce knowledge transfer

2. Association for Molecular Pathology vs Myriad Genetics, US Supreme Court, June 13th 2013, N° 12398.

3. The paid open access notion is derived from the works of Gadaud *et al.* [2010]. They write: "owners are paid to maintain an open access."

4. In the early 2000s, Celera Genomics provides access to its human genome database on the basis of a paid open access: the access price to the database is US$ 15 million per year without other consideration, the payment is therefore before the innovation that could be created by the contractor.

between two firms. Our main contribution to this literature is the introduction of paid open access as an alternative to the patent to transfer knowledge. 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 Meurer [1989]. The patent part of our model is very close to Llobet [2003]. We introduce in this type of model the open access solution as a competing solution for the innovator to sell knowledge to a competitor.

The rest of the paper is structured as follows. We first present the framework of our analysis, then provide the results starting with the choice between the secret and the paid open access without patent. Next we introduce the patent and conclude on the impact of the patent on the choice of paid open access. All formal proofs are grouped in a final technical appendix.

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 is not aware of 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. The parameter γ could be also interpreted as the inverse distance between both applications[5].

The upstream innovator can adopt one of the three following strategies regarding the basic innovation:

Paid open access

Firm I proposes to the downstream firm to have open access to the basic innovation at a fixed price F. The open access means that the uses of the

5. We can consider for instance the Salop circle and denote by $\frac{1}{\gamma}$ the distance between both firms. In that case we have $\frac{1}{\gamma} \in [0, L]$ where L is the length of the circle.

innovation is unconditional. The unconditionality precludes contractually any type of litigation *ex post*[6]. 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 is a duopoly profit denoted by $\pi^d(\gamma)$. We assume that the higher the 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 $\delta \in [0,1]$). Parameter δ captures the impossibility for firm I to fully protect the basic innovation in the absence of secrecy and patent. Firm E then earns an expected profit equal to $\delta\pi^d(\gamma)$ and the expected profit of firm I is equal to $\delta\pi^d(\gamma) + (1-\delta)\pi^m$ where π^m is the monopoly profit earned by firm I when firm E does not innovate.

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 π^m.

The Patent

The upstream innovator patents the basic innovation. Knowledge disclosure allows the downstream firm to develop its own application. Nevertheless the patent holder, firm I, can require a licence from firm E. If firm E refuses the licence contract, its application is likely to infringe on the patent. The probability, x, of infringement depends on the technical characteristics of the application. We assume these characteristics and thus variable x are firm E private information. For simplicity we consider that there is infringement $(x=1)$ with probability $\frac{1}{2}$ and no infringement otherwise $(x=0)$. If the upstream innovator sues firm E for infringement in case of disagreement on the licence contract, both firms incur a cost C. When the court considers that 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. 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. Hence the profit of both firms are $\pi^I(r,\gamma)+P$ for firm I and $\pi^E(r,\gamma)-P$ for firm E. There exists a royalty rate that maximizes the joint profit $\pi^I(r,\gamma)+\pi^E(r,\gamma)$. We denote by r^* such a royalty rate and the corresponding joint profit is equal to $\Pi(\gamma)$. Profit $\Pi(\gamma)$ decreases with γ. The royalty rate softens competition and could allow both firms to share the monopoly profit for both applica-

6. Contractually paid open access allows all future uses of the innovation without compensation or royalty.

tions[7]. Therefore we have $2\pi^{d}(0) = \Pi(0)$ and $\Pi(\gamma = +\infty) = \pi^{m}$. We assume that $\Pi(\gamma) - 2\pi^{d}(\gamma)$ is positive and increases with γ because of the competition softening effect of the royalty rate.

2.2. The game

We consider two different options in terms of intellectual property right law for the basic innovation. In the first configuration, the usefulness requirement of the patent office is soft and thus the basic innovation can be patented. The timing of the game is the following (see also figure 1):

1. Firm I 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 fixed cost F (paid open access).

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 and decides to produce, firms go to trial[8].

In the second configuration, the patent law is more restrictive 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 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 paid open access. For that purpose, we study first the benchmark case where the basic innovation cannot be patented and then, we introduce a patent for the basic innovation.

3. Paid open access versus secret without patent

In the absence of patent a basic innovation, firm I can either keep the basic innovation secret or propose paid open access to firm E. The strategy

7. For the softening competition effect of a royalty rate, see for instance Farrell and Shapiro [2008].

8. 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.

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

Proposition 1 *In the absence of patent for the basic innovation, there exists a competition toughness threshold,* $\gamma^{OA}_{NoPatent}(\delta)$*, such that the upstream innovator chooses to keep the basic innovation secret as long as* $\gamma > \gamma^{OA}_{NoPatent}(\delta)$ *and shares knowledge with firm* E *otherwise (the paid open access solution).*

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

If firm I decides to share knowledge with a paid open access contract 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 have an open access to the basic innovation. Otherwise, firm E would prefer to try to develop the application by itself. Firm I then earns $(2-\delta)\pi^d(\gamma)$. Clearly, the higher the competition, the lower the profit earned in case of paid open access because of a lower duopoly profit. Hence the critical level of competition $\gamma^{OA}_{NoPatent}(\delta)$ 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 share knowledge. That is why the threshold $\gamma^{OA}_{NoPatent}(\delta)$ decreases with δ.

This result should be considered as the benchmark case where the absence of patent option leads the innovator to use the secret as long as competition is high enough.

4. Paid open access 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 paid open access to the other firm. We determine first the expected profit following the patenting of the basic innovation. Then we derive the profits induced by paid open access 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 on the patent.

Lemma 1 *At the Perfect Bayesian Equilibrium of the game, firm E of type $x = 1$ always accepts the licence contract proposed by firm I while firm E of type $x = 0$ accepts the licence contract for γ above a threshold $\hat{\gamma}$.*

We show in that lemma that the risk of trial depends on the level of competition on the market for applications. Tough competition reduces the risk of litigation. Let us explain 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 optimally 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 joint profit, $\Pi(\gamma)$, according to the probability of dependence x. Asymmetric information on the parameter x prevents 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 sets a high P, if firm E is sure to win the trial (type $x = 0$), firm E may refuse the licence contract. A lower fixed fee reduces the licence revenue but may also induce firm E to accept the licence. 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 $1 - x$ 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. Thus the cost to refuse the licence contract increases if the competitive pressure is higher. As a result, tough competition makes easier the acceptance of the licence contract by firm E.

We can deduce the expected profit of both firms. We denote by $\Pi^E_{Patent}(\gamma)$ the profit earned by firm E and by $\Pi^I_{Patent}(\gamma)$ 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 $\Pi(\gamma) - \frac{1}{2}(\Pi(\gamma) - 2\pi^d(\gamma)) - C$ if $\gamma < \hat{\gamma}$ and equal to $\Pi(\gamma)$ otherwise.*

We capture in this lemma the inefficiency of the patent. We showed that both firms do not avoid costly litigation if competition is low enough. The inefficiency is twofold: both firms earn the duopoly profit rather than $\Pi(\gamma)$ and incur litigation costs. In other terms, soft competition compounds the impact of asymmetric information on the innovation characteristics of firm E by reducing the chance of agreement. Instead, the toughness of competition lowers the patent inefficiencies.

4.2. Patent versus paid open access

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

Proposition 2 *The choice between patent, paid open access and secret gives rise to the following decision rule: there exist two thresholds of the competition toughness* γ^{P}_{Patent} *and* γ^{OA}_{Patent} *such that for any* $\gamma > \gamma^{P}_{Patent}$, *the firm* I *patents the basic innovation while for any* $\gamma < \gamma^{OA}_{Patent}$, *both firms agree on the paid open access option. For* $\gamma^{OA}_{Patent} < \gamma < \gamma^{P}_{Patent}$, *the secrecy may dominate the patent solution for some* γ.

The patent may promote paid open access since for some δ, *we have* $\gamma^{OA}_{Patent} > \gamma^{OA}_{NoPatent}(\delta)$.

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, paid open access avoids 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 if firm E accepts the licence contract, competition is softened. The secrecy preserves the monopoly profit but firm E does not enter and thus firm I does not earn revenue from access to its basic innovation.

Let us explain the outcome of this trade-off.

First, if we compare the patent solution with the secrecy, the patent is more profitable for high levels of competition. Indeed, the competition induces firm E to accept the licence contract and thus litigation is avoided. For lower level of competition, the level of litigation costs could make the secrecy more profitable than the patent.

The choice between paid open access and patent gives rise to the following trade-off. On the one hand, paid open access avoids litigation costs. 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 access fee paid by firm E. This fee depends on the expected profit of firm E if the firm refuses to pay. On the other hand, the patent is likely to constrain firm E to accept a licence contract. That licence contract increases the profit of firm I through the licence revenue itself as well as through the competition accommodating impact of the royalty rate. Notwithstanding, if firm E refuses the contract proposed, firm I incurs a litigation cost. Thus the comparison between the patent and paid open access 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 paid open access. In lemma 1, we stressed that the probability of litigation increases if the competitive pressure γ decreases. Hence the existence of the threshold γ^{OA}_{Patent} of the level of competition below which firm I prefers the paid open access. In other words, a high level of competition deters paid open access for two main reasons. First, the patent avoids tough competition thanks to the royalty rate that softens competition and 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 paid open access 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 paid open access even for very low level of competition. Thus it is the presence of of litigation costs magnified by soft competition that leads the innovator to prefer paid open access.

To determine to what extent the introduction of the patent undermines paid open access we must compare the threshold $\gamma^{OA}_{NoPatent}(\delta)$ with γ^{OA}_{Patent}. It is easy to show that for $\delta = 1$, we have $\gamma^{OA}_{Patent} > \gamma^{OA}_{NoPatent}(1) = 0$. In that case, the patent does not deter paid open access at all. Rather, the patent promotes the knowledge transfer through paid open access since for the range of γ equal to $[\gamma^{OA}_{NoPatent}(\delta), \gamma^{OA}_{Patent}]$, the patent allows paid open access whereas without patent firm I prefers the secrecy.

Let us explain why the patent encourages the open access solution for high values of δ. The patent increases the expected profit of firm I whenever firm E refuses to pay for an open access. This higher profit is due to a better protection of the basic innovation under patenting than without patenting. When firm I negotiates the access price in case of paid open access, the patent increases its bargaining power and thus allows firm I to increase the price of paid open access. 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 prefers paid open access in order to avoid any litigation cost. This is the reason why the introduction of the patent is likely to promote the open access solution as far as litigation costs remain high. If firm E has a low probability to innovate if it refuses the paid open access contract, the bargaining power of firm I is high even without patent. This is the case whenever δ is low. Here, the paid open access 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 paid open access and thus the patent deters paid open access.

5. Conclusion

We develop in this paper a framework to analyze the impact of the patentability of basic innovations. For that purpose, we consider a firm that can use a basic innovation to develop an application. The basic innovation can also lead another firm to develop a different application. We first determine the incentives for the basic innovator to either share knowledge with the competitor with paid open access to the basic innovation or to keep the basic innovation secret. Then, we contrast the emergence of paid open access with and without patent for the basic innovation. We stress the key role played by the patent by showing that paid open access emerges more often if the company that owns the basic innovation has the option to protect it by a patent. In that sense, we argue that patent option could be crucial to promote paid open access. We can contrast our result with Green and Scotchmer [1995]. They show that the existence of a strong broad patent leads the downstream innovator to negotiate an ex-ante license agreement whereas we argue that the weakness of the broad patent (the risk to loose the trial and pay litigation costs) leads the upstream innovator to prefer an ex-ante knowledge sharing agreement rather than an *ex post* licence contract. Nevertheless, it worth noting that in both models, the access to knowledge (upstream innovation) is facilitated by the existence of a patent on the basic innovation.

6. Appendix

Proof of proposition 1

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

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

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

Proof of lemma 1 and lemma 2

1. Firm E of type $x=1$ accepts P at most at $\pi^E(r,\gamma)$

Firm E of type $x=0$ accepts P at most at $\pi^E(r,\gamma) - Max(\pi^d(\gamma) - C, 0)$

We then deduce that if $\pi^d(\gamma) - C < 0$, firm I sets P at $\pi^E(r,\gamma)$ and gets $\pi^I(r,\gamma) + \pi^E(r,\gamma) - \pi^d(\gamma)$.

Otherwise, firm I compares $\pi^I(r,\gamma) + \pi^E(r,\gamma) - \pi^d(\gamma) + C$ with $\frac{1}{2}(\pi^I(r,\gamma) + \pi^E(r,\gamma)) + \frac{1}{2}(\pi^d(\gamma) - C)$.

It is easy to show that the rate r is set at r^* to maximize $\pi^I(r,\gamma) + \pi^E(r,\gamma)$.

Firm I thus compares $\Pi(\gamma) - \pi^d(\gamma) + C$ with $\frac{1}{2}\Pi(\gamma) + \frac{1}{2}(\pi^d(\gamma) - C)$.

The difference, $\frac{1}{2}(\Pi(\gamma) - 3\pi^d(\gamma) + 3C)$, increases with γ. For $\gamma = 0$, we have $\frac{1}{2}(\Pi(0) - 3\pi^d(0) + 3C) = \frac{1}{2}(-\pi^m + 3C)$. For γ high, we have $\frac{1}{2}(\Pi(\gamma) - 3\pi^d(\gamma) + 3C) = \frac{1}{2}\Pi(\gamma) > 0$.

Thus, there exists a unique threshold $\hat{\gamma}$ such that I proposes a P accepted by firm E of type $x = 0$ if $\gamma > \hat{\gamma}$.

2. Payoffs and probability of litigation at the equilibrium

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

firm I:

$$\Pi^{I}_{Patent}(C, \gamma) = \begin{cases} \Pi(\gamma) - Max(\pi^{d}(\gamma) - C, 0) \text{ if } \gamma > \hat{\gamma} \\ \frac{1}{2}\Pi(\gamma) + \frac{1}{2}(\pi^{d}(\gamma) - C) \text{ if } \gamma < \hat{\gamma} \end{cases}$$

firm E

$$\Pi^{E}_{Patent}(C, \gamma) = \begin{cases} \frac{1}{2} Max(\pi^{d}(\gamma) + C, 0) \text{ if } \gamma > \hat{\gamma} \\ \frac{1}{2}(\pi^{d}(\gamma) - C) \text{ if } \gamma < \hat{\gamma} \end{cases}$$

We deduce the sum of both profits:

$$\Pi^{I}_{Patent}(C, \gamma) + \Pi^{E}_{Patent}(C, \gamma) = \begin{cases} \Pi(\gamma) \text{ if } \gamma > \hat{\gamma} \\ \frac{1}{2}\Pi(\gamma) + \pi^{d}(\gamma) - C \text{ if } \gamma < \hat{\gamma} \end{cases}$$

Proof of proposition 2

(i) Patent against secrecy

For very high value of γ, $\Pi^{I}_{Patent}(\gamma) = \Pi(\gamma) > \pi^{m}$: the patent solution is more profitable than the secret.

For $\gamma = 0$, we have $\Pi^{I}_{Patent}(\gamma) = \frac{1}{2}\Pi(0) + \frac{1}{2}(\pi^{d}(0) - C) = \frac{3}{2}\pi^{m} - \frac{1}{2}C > \pi^{m}$ if C is low as assumed.

In addition, for intermediate values of γ, $\Pi^{I}_{Patent}(\gamma) = \Pi(\gamma) - \pi^{d}(\gamma) + C$. As long as this expression is lower than π^{m}, the secret is more profitable than the Patent for these intermediate values of γ. The patent solution is more profitable than the secret otherwise. Let us denote by γ^{P}_{Patent} the threshold value of γ above which the Patent is always more profitable than the secret.

(ii) Patent against paid open access

As long as $\Pi^{I}_{Patent}(C, \gamma) < \delta\pi^{d}(\gamma) + (1 - \delta)\pi^{m}$, the patent is irrelevant for firm I.

Whenever $\Pi^{I}_{Patent}(C, \gamma) > \delta\pi^{d}(\gamma) + (1 - \delta)\pi^{m}$, if firm I proposes paid open access to firm E, the price proposed is equal to:

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

This configuration exists for low values of γ.

Then, paid open access is preferred as long as $2\pi^{d}(\gamma) > \Pi^{E}_{Patent}(C, \gamma) + \Pi^{I}_{Patent}(C, \gamma)$

We have:

$$\Pi^{I}_{Patent}(\gamma) - (\pi^{d}(\gamma) + F) = \Pi^{E}_{Patent}(\gamma) + \Pi^{I}_{Patent}(\gamma) - 2\pi^{d}(\gamma)$$

$$= \begin{cases} \Pi(\gamma) - 2\pi^{d}(\gamma) \text{ if } \gamma > \hat{\gamma} \\ \frac{1}{2}\Pi(\gamma) - \pi^{d}(\gamma) - C \text{ if } \gamma < \hat{\gamma} \end{cases}$$

By assumption, the function increases with γ. In addition for $\gamma = 0$, we have $\frac{1}{2}\Pi(0) - \pi^{d}(0) - C = -C$ and for high values of γ, we have $\Pi(\gamma) - 2\pi^{d}(\gamma) > 0$.

We deduce that there exists a unique threshold $\gamma^{OA/P}$ such that open access is preferred to patent if $\gamma < \gamma^{OA/P}$.

We deduce from points (i) and (ii) that there exists a threshold γ^{OA}_{Patent} such that for $\gamma < \gamma^{OA}_{Patent}$, the paid open access is the most profitable choice for firm I and that there exists a threshold γ^{P}_{Patent} such that for $\gamma > \gamma^{P}_{Patent}$, the patent is the most profitable solution. In between, the secrecy may be the most profitable solution for some γ.

(iii) Comparison of both thresholds γ^{OA}_{Patent} and $\gamma^{OA}_{NoPatent}(\delta)$.

For high values of δ, we have $\Pi^{I}_{Patent}(\gamma) > \delta\pi^{d}(\gamma) + (1-\delta)\pi^{m}$ for any γ and thus the patent increases the profitability of paid open access for any γ. Because $\gamma^{OA}_{NoPatent}(\delta)$ decreases if δ increases, it follows that $\gamma^{OA}_{NoPatent}(\delta) < \gamma^{OA}_{Patent}$ for low values of δ.

References

ANTON J. J. and YAO D. A. [2004], "Little Patents and Big Secrets: Managing Intellectual Property", *Rand Journal of Economics.*, 35(1), p. 1-22.

AOKI R. and HU J. L. [1999], "Licensing vs. litigation: The effect of the legal system on incentives to innovate," *Journal of Economics and Management Strategy*, 8(1), p. 133-160.

D'ASPREMONT C., BHATTACHARYA S. and GERARD VARET L. A. [2000], "Bargaining and Sharing Innovative Knowledge", *Review of Economic Studies*, 67(2), p. 255-271.

BHATTACHARYA S. and GURIEV S. [2006], "Patents vs Trade Secrets: Knowledge licencing and spillover", *Journal of the European Economic Association*, 4(6), p. 1112-1147.

ERKAL N. [2005], "Optimal licensing policy in differentiated industries". *The Economic Record*, 81(252): p. 51-60.

FARRELL J. and SHAPIRO C. [2008], "How Strong are Weak Patents", *American Economic Review*, 98(4), p. 13-47.

GADAUD J. and RAMBONILAZA M. [2010], "Amenity Values and Payment Schemes for Free Recreation Services from Non-industrial Private Forest Properties: A French Case Study", *Journal of Forest Economics*, 16(4), p. 297-311.

GOLD E. R. and CARBONE J. [2010], "Myriad Genetics: In the Eye of the Policy Storm." *Genetics in Medicine*, 12(4), p. S39-S70.

GREEN J. and SCOTCHMER S. [1995], "On the Division of Profit in Sequential Innovation", *Rand Journal of Economics*, 26(1), p. 20-33.

HENRY C., TROMMETTER M. and TUBIANA L. [2003], *"Innovation et droits de propriété intellectuelle: quels enjeux pour les biotechnologies?"*, Rapport au Conseil d'Analyse Économique n° 41, La Documentation Française, p. 49-112.

LLOBET G. [2003], "Patent Litigation when innovation is cumulative", *International Journal of Industrial Organisation*, 21, p. 11-35.

MEURER M. J. [1989], "The Settlement of Patent Litigation", *Rand Journal of Economics*, 20(1), p. 77-91.

SCOTCHMER S. [2005], *"Innovation and Incentives"*. Cambridge: MIT press, 352 pages.

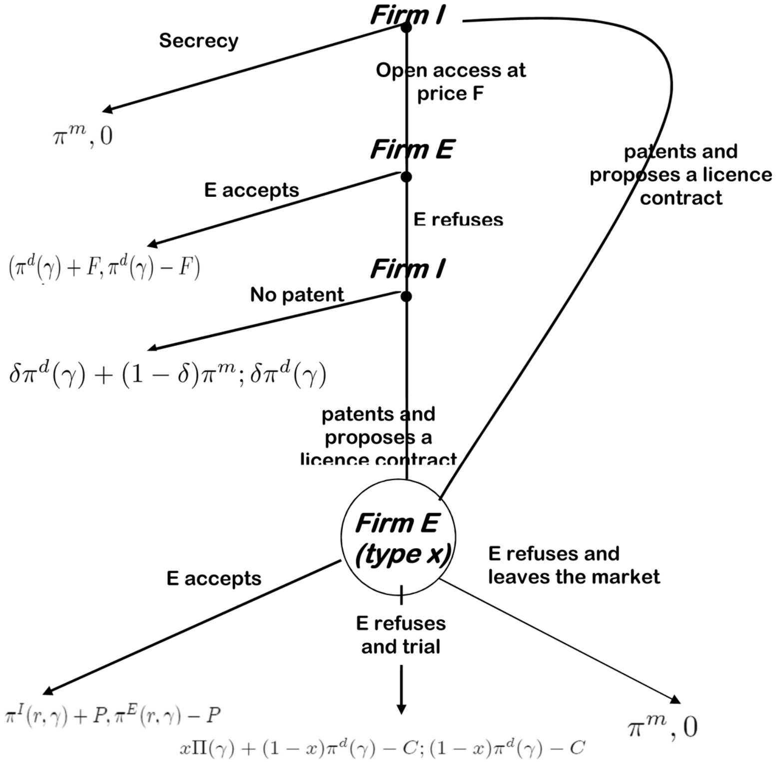

Figure 1. The game