Strategic Patenting Decision and Barrier to Entry

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Abstract

In this paper we investigate whether a patent can be a strategic barrier to entry. Indeed, patent protection restricts entry rather than preventing it. A potential entrant can enter a market if his product does not infringe on the current patent: he must respect a legal novelty requirement. We consider a model of process innovation in which the demand can be either low or high. We show that when the information concerning the demand is symmetric, high demand will always attract a potential entrant, even though he must respect the novelty requirement. As the patentholder cannot deter entry, she can just save the renewal cost if she does not renew her patent. However, for low demand, the renewal of the patent is sufficient to deter entry. Nevertheless, if the patentholder has more information concerning the demand size than her potential competitor, we show that she will want to pretend that the demand is low to signal a low profitability of entry. Thus, the renewal decision will be strategic to deter entry and the patent can be a strategic barrier to entry.

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1 Introduction

Patents are usually seen as barriers to entry created temporarily by the government. However, in most cases, patent protection restricts entry rather than preventing it. A new entrant can enter a market if his product does not infringe on the current patent: he must respect a minimum novelty requirement. If we consider the specific case of process innovation, a potential entrant must reduce his production costs below a threshold imposed by the patent laws, namely the height of patent protection\(^1\). In this setting we show that if the market is profitable enough, the potential entrant will enter with an improvement of the process innovation and thus, both firms will be engaged in a duopoly competition. As the patentholder cannot prevent legal entry, she can at least save the renewal cost if she decides not to renew her patent. This is due to the restriction imposed by the government that does not fully protect the patentholder, but rather makes the entrant a stronger competitor. On the contrary, if the profitability is low, the mere constraint imposed by the government prevents entry, and the patentholder is better off if she renews her patent. Indeed, it is too costly for the entrant to enter the market and the patent is an effective barrier to entry. Thus, we point out that depending on the market profitability, a patent either can be a barrier to entry or, on the contrary, can even make the entrant a stronger competitor. However, when we posit the assumption of asymmetric information concerning the demand, we show that if the patentholder is better informed than her potential competitor, the patent can be a strategic barrier to entry via the renewal decision. Indeed, the patentholder may try to convey the information that the demand is low, and thus decide to renew her patent strategically. The renewal decision will not give any information to the less-informed firm, and the entry will occur less often. Thus, when the firms do not have the same information, the strategic behavior of the patentholder will reduce the likelihood of entry of her competitor. The main point of our paper is to show that the role of the patent as a barrier to entry that may be weakened in the case of process innovation under symmetric information can be restored in the case of asymmetric information. Therefore, the information possessed by the entrant on the demand of the product determines the efficacy of the protection of the patentholder on the process to produce the product.

The patent literature has extensively studied the policy implication of different patent requirements, and in particular the trade-off between the duration of a patent and the scope of

\(^1\)In fact there is no clear definition of the height of patent protection and we adopt the definition of van Dijk (1996). A formal definition of the different dimensions of the patent protection will be given at the end of the introduction.
the protection (Klemperer (1990), Gilbert and Shapiro (1990), Scotchmer and Green (1990), Gallini (1992), Denicolò (1996)). Little attention has been devoted to the use of the patent system by innovators beside the benefit cost-analysis. The papers by Horstman, Mac Donald and Slivinsky (1985) and Crampes and Langinier (1998) are among the few contributions to consider the strategic use of patents. Nevertheless, there exists a significant empirical patent literature that attempts to explain the behavior of innovators as far as patents and R&D are concerned (Cohen, Nelson and Walsh (2000) for one of the most recent work). From these studies it seems that innovators claim that patents are the least effective mechanism for protecting invention. However, the recent surge in US patents attests on the contrary that innovators do patent and this is especially true in industries like biotechnology or software industries for instance. A first attempt to explain this recent surge comes from Kortum and Lerner (1999). For them, the recent jump may be due to a change in management of innovation. Using data from the semi-conductor industry, Hall and Ham-Ziedonis (2001) explain this jump by the “pro-patent” shift in the US legal environment in early 1980s and by a strategic management of patent portfolios. Indeed, under certain circumstances firms take their patenting decision strategically. This can be done for different purposes: in order to keep or establish their position in a technological domain, to block rivals from patenting related inventions, to expend their portfolio even with lower quality patents for a defensive strategy (Hall and Ham-Ziedonis (2001) in the semiconductor industry) or even to use in negotiation with other firms as related in Cohen, Levin and Walsh (2000). Our paper is an attempt at explaining that firms do renew their patent in order to strategically deter entry of rivals in related areas.

As mentioned earlier, we are concerned with the height of patent. We now define more precisely what we mean by height of patent. There are different components to consider in the definition of the height. As identified by O’Donoghue (1998), the patent literature has extensively used the terms “breadth”, “patent scope”, “patent protection” and “novelty requirement” without veritable common definitions for each of these terms. According to O’Donoghue, the two distinct issues in patent law are the following: first, when should a patent be granted, and second, what products can infringe on the patent. The first issue is termed the “patentability requirement” and is related to the novelty requirement. The second issue has two components: the breadth and the height. The former offers the innovator a protection against imitators

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2 See O’Donoghue (1998) for a complete review of the terms commonly used in the patent literature.

3 It is where we depart from O’Donoghue (1998), just from the terminological point of view. For him, there is only one dimension, the breadth, and he distinguishes two kinds of breadth: the lagging breadth (breadth for us) and the leading breadth (height for us). Note that Klemperer (1990) and van Dijk (1996) were among the first
while the latter offers protection against future innovators.

In accordance with O’Donoghue (1998), we consider three different dimensions. Two of them are related to the height while one is related to the breadth. Here, we only consider the height in both its components. First, the “patentability requirement” or legal novelty requirement is imposed by the government. This is one aspect of the height, namely the minimum level of novelty required by law to patent an innovation. By imposing a weak requirement in the Green and Scotchmer (1995)’s sense, which is allowing new innovators to patent all the possible improvements, the government promotes the diffusion of the innovation. As a result innovators are more quick to patent. Conversely, by imposing a strong requirement, the law protects the first innovator, and resultingely increases the delay in the disclosure of the innovation. Once the innovator has respected the legal novelty requirement, she has to choose the level of her own protection, namely the novelty assignment. This is the second component of the height: the protection that the innovator will claim in case of litigation. Even if this component has to be chosen by the innovator herself, it can follow a bargaining process with the Patent Office over the scope of the claim.\footnote{We thank V. Denicolo for pointing that out.}

To summarize, the height has two components: the legal novelty requirement which is imposed by the government, and the novelty assignment, which is mostly at the discretion of the innovator herself. Here, we are essentially concerned about the legal novelty requirement imposed by the government.

The model is the following. An innovator initially holds a patent on a process innovation. This patent endows her a protection on different products that are produced using this process. A potential entrant has to decide whether to enter the market with a given differentiated product and use an improved version of the process. However, the new entrant can only enter the market if he improves on the process innovation, via a reduction of production costs. In effect, a patent here does not prevent entry entirely, but rather it restricts it. The new entrant must respect the minimum novelty requirement imposed by the laws in order to enter the market without infringing on the existing patent. Furthermore, we assume that there exists an asymmetric information. Specifically, only the patentholder knows the value of the demand which can have a small or large size. The new entrant only has prior beliefs about the value of the demand.\footnote{Eswaran and Gallini (1996) propose a model in which both process and product innovation are considered. Our definition is closely related to their definition of the height.}
Due to the asymmetric information, the patentholder decides strategically whether to renew or not.

We consider a two-stage game where, in the first stage, the patentholder decides whether to renew her patent or not, and the potential entrant decides whether to enter or not. In the second stage, both firms decide their level of production and the entrant must determine the level of investment he is willing to allocate towards reducing production costs. If the patentholder renews her patent and the entrant decides to enter, he must enter the market with a new process in order not to infringe on the existing patent. After determining the optimal payoffs in the second stage of the game, we determine the optimal decisions in the first stage of the game. In the case of perfect information, both firms have the same information concerning the value of the demand. If the entry cost is a natural barrier for the new entrant, he will not enter if the patentholder renews her patent. It turns out to be the case when the demand is low, where the patent, via the renewal decision, prevents entry. However, this is no longer true for high demand, in which case the patent is no longer an effective barrier to entry but, on the contrary makes the competition tougher.

Under asymmetric information, the patentholder strategically decides on renewal. Indeed, she knows that the new entrant will try to infer information via observing her decision. As the entry cost due to the existence of a patent is a natural barrier in the case of small demand size, the patentholder will try to pretend that the demand is low, and thus will decide to renew when the entrant has low prior beliefs. On the contrary, if he has high prior beliefs, the patentholder will randomize her renewal decision. When the demand size is large enough, she will choose randomly to renew her patent. The observation of the renewal decision cannot provide information to the potential entrant. As a result, he also randomizes his entry decision. It follows that under asymmetric information, the potential entrant will enter less often than in the case of perfect information. Thus, the patentholder renews her patent to deter entry.

The organization of the paper is the following. In section 2 we set up the model and present the timing of the game. In section 3 we introduce the production and investment subgame. We determine the optimal payoffs for each firm. In section 4, we determine the Perfect Nash equilibrium when the information is perfect. We introduce the imperfect information structure in section 5 and we determine the Perfect Bayesian Equilibrium. Section 6 concludes and presents future extensions.
2 The Model

Consider two firms: a patentholder and a potential entrant who wants to enter the protected market. In order to enter, he must respect the constraint enforced by the government, namely the novelty requirement. He has to sufficiently reduce his production costs to respect the improvement claims. According to most European patent laws, the patentholder must pay an annual renewal fee to keep her patent in force\(^7\). If not, the patent is permanently cancelled, and the potential entrant gains the right to enter freely.

There exists an asymmetric information with regards to the value of the demand: only the patentholder knows if the value of the demand is low or high. She may therefore act strategically and no reveal the true value of the demand. She must decide whether to renew her patent or not. The potential entrant then observes the patentholder’s decision and tries to infer information from this observation. Based on this, he must decide whether to enter the market or not.

While the patent is kept in force, entry is just restricted. The production cost of the new product has to be sufficiently low relative to the costs incurred by the incumbent. The potential entrant has to invest in order to reduce his costs so as to respect the legal novelty requirement. This is one component of the patent height, the minimum level of improvement needed to use a patented process without infringing it.

Both firms do not have the same production cost function nor the same “entry” costs. For the incumbent, the “entry” cost is the renewal fee if she decides to pay it\(^8\). For the potential entrant, entry costs include the installation of the plants and the marketing of the product. Additionally, the entrant must pay to reduce his production costs. We assume that the potential entrant’s entry cost is high enough to prevent him from entering the market when demand is low.

The model is described in a two period game:

- in the first period, the patentholder decides whether to pay the renewal fee or to give her patent up. The potential entrant observes this decision and decides to enter or not to enter. In the asymmetric information case, the incumbent knows whether demand is high (demand intercept \(\alpha_h\)) or low (\(\alpha_\ell\)), where \(\alpha_h > \alpha_\ell\), while the entrant only has priors about the States of Nature: \(\rho\) denotes the probability that demand is high;

- the second period is an investment and production game where both firms have the same information. If, in the first period, the potential entrant did not enter, the incumbent

\(^7\)Since the early 1980’s, US law has introduced a renewal fee: the patentholder has to renew her patent at third, seventh and eleventh years.

\(^8\)Here, we rule out the cases in which the patentholder may decide to improve on the process innovation.
would now have a monopoly position to choose her output. If the potential entrant did enter, it follows that since the potential entrant now knows the demand, the subgame is a perfect information game where first the entrant chooses his investment with respect to cost reduction, and second where both firms compete in quantities\(^9\).

Using the classical backward induction argument, we first determine the Cournot equilibrium and the investment of the post-entry subgame in section 3. Following this, section 4 characterizes the Perfect Bayesian Equilibria of the complete game restricted by the constraint imposed by the government to protect innovations.

### 3 Investment and Production Subgame

We compute the equilibrium quantities sold by firms when both have perfect information about the market profitability. Three alternative market situations are possible:

- if the potential entrant does not enter, the incumbent is a monopolist;
- if the potential entrant enters and the patent is no longer in force, the market is a duopoly. The level of cost reduction is determined by the entrant without any restriction before firms produce and it is known by both;
- finally, if the potential entrant enters the market when the patent is still in force, he must respect patent laws, that is he cannot infringe on the incumbent’s rights. He is forced to invest in cost reduction of at least a minimum amount determined by the government. Knowing this reduction level, both firms then compete in quantities.

#### 3.1 Choice of Quantities

The demand for product from each firm \(i = H, E\) is represented by:

\[
p_i(q_i, q_j) = \alpha - q_i - \beta q_j \quad \text{for} \quad j \neq i, \tag{1}
\]

where \(\alpha \in \{\alpha_f, \alpha_h\}\) is an index of market profitability and \(\beta\) is a differentiation parameter where \(\beta \in [0, 1]\). The fact that \(\beta = 0\) implies that the potential entrant has entered a market different\(^9\).

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\(^9\)We assume that the process innovation is not drastic.
from the incumbent’s market, resulting in two juxtaposed monopolies. On the contrary, \( \beta = 1 \) indicates perfect substitutes. The differentiation parameter is perfectly exogenous\(^{10}\).

The inverse demand function (1) can be interpreted as the marginal utility of product \( i \). The utility function of the representative consumer is

\[
 u(q_E, q_H) = \alpha(q_E + q_H) - \frac{1}{2}(q_E^2 + q_H^2) - \beta q_E q_H. \tag{2}
\]

We assume that both firms do not have the same production cost function. Let \( c_H \) represent the production cost of the incumbent and \( c_E \) the production cost of the potential entrant, with\(^{11}\) \( c_E < c_H < \alpha \). Furthermore, we assume that \( \alpha - c_H \) must be big enough to insure the existence of interior solutions.

We first determine the socially optimal quantities. These quantities are determined by the solution of

\[
 \max_{q_E, q_H} u(q_E, q_H) - c_E q_E - c_H q_H,
\]

and their values are

\[
 q_i^0 = \frac{m_i - \beta m_j}{1 - \beta^2} \quad i \neq j \text{ and } i, j = E, H.
\]

where \( m_i = \alpha - c_i \) represents firm \( i \)'s size of demand\(^{12}\). The maximal social welfare is thus

\[
 V(q_E^0, q_H^0) = \frac{m_E m_H}{1 + \beta} + \frac{(m_E - m_H)^2}{2(1 - \beta^2)}. \tag{3}
\]

Second, we consider the case of a private monopoly, which corresponds to the situation where the potential entrant decides to not enter, and thus the patentholder is in a monopolistic situation. The problem of the patentholder is then

\[
 \max_{q_H} (\alpha - q_H - c_H)q_H.
\]

So, she produces \( q_H^M = m_H/2 \) and her equilibrium profit is

\[
 \Pi_H^M = \frac{m_H^2}{4}. \tag{4}
\]

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\(^{10}\)We study the case of an endogenous determination of the differentiation parameter in a model in which the entrant has to respect a differentiated constraint in Crampes and Langinier (1998). The structure of the model is similar except that here the constraint is on the cost of production and not on the differentiation parameter. The results are highly dependent on the chosen constraint.

\(^{11}\)This inequality makes sense if we consider that the potential entrant has already done a reduction of cost after the introduction of the patent due to spillover effects.

\(^{12}\)To insure these values to be positive, we assume that \( \beta < \min \frac{m_H}{m_E} \).
As a third case, consider the duopoly structure with differentiated demands (1). Recall that there is perfect information about $\alpha$. Firm $i = E, H$ solves
\[
\max_{q_i} (\alpha - q_i - \beta q^*_j - c_i) q_i \quad j \neq i.
\]
It is straightforward to calculate the equilibrium quantities
\[
q^*_E = \frac{2m_E - \beta m_H}{4 - \beta^2},
\]
\[
q^*_H = \frac{2m_H - \beta m_E}{4 - \beta^2},
\]
and the equilibrium profits are
\[
\Pi^*_i = \left( \frac{2m_i - \beta m_j}{4 - \beta^2} \right)^2 \text{ where } i \neq j \text{ and } i, j = H, E. \tag{5}
\]
We are now in position to determine the level of investment that is required of the entrant in order to reduce his production costs.

### 3.2 Choice of Investments

We now assume that the potential entrant can modify the production cost by his investment $I$. This investment level is chosen after entry has occurred. We denote $m_E(I) = \alpha - c_E(I)$ where $c_E(I)$ is such that $c'_E(I) < 0$, $c''_E(I) > 0$ and $-c''_E(I)[2(\alpha - c_E(I)) - \beta(\alpha - c_H)] + 2(c'_E(I))^2 < 0$.\(^{13}\) Thus $m'_E(I) > 0$ and $m''_E(I) < 0$.

When the incumbent has not paid the renewal fee, the entrant is free to choose $I$ to maximize his net profit:
\[
\max_I \left( \frac{2m_E(I) - \beta m_H}{4 - \beta^2} \right)^2 - I - a_E
\]

The optimal investment $I^*$ is the solution of
\[
\frac{4m'_E(I) [2m_E(I) - \beta m_H]}{(4 - \beta^2)^2} - 1 = 0 \tag{6}
\]

Nevertheless, the potential entrant must respect an entry constraint and cannot freely choose his level of production cost as the government forces him to incur production costs that respect a constrained level.

\[^{13}\]This condition will be satisfied for an exponential cost function $c_E(I) = ce^{-I}$ and $\beta < \frac{2^{\frac{\alpha - 2c_E(I)}{\alpha - c_H}}}.$
The public authority program is the following:

$$\max_I \frac{m_E(I)m_H}{1+\beta} + \frac{(m_E(I) - m_H)^2}{2(1-\beta^2)} - I - a_E - a_H.$$ 

The optimal investment $I^o$ is the solution of

$$m'E(I) \left[ \frac{m_H}{1+\beta} + 2 \frac{m_E(I) - m_H}{1-\beta^2} \right] - 1 = 0.$$ 

(7)

The comparison of both the levels of investments leads to the following result.

**Proposition 1**: For a given level of differentiation that satisfies $\beta < \frac{m_H}{m_E(I^*)}$, $I^o > I^*$. 

**Proof.** The comparison of the first order conditions is the following. We first evaluate the first order condition (7) at $I^*$. Thus, from (6) we have $m'E(I^*) = \frac{(4-\beta^2)^2}{4[2m_E(I^*)-m_H\beta]}$ which we introduce in (7). In doing so, we obtain

$$\frac{1}{(1-\beta^2)(4-\beta^2)^2} \left[ m_H (-\beta^5 + 4\beta^3 - 12\beta) + m_E(I^*) (\beta^4 + 8) \right]$$

(8)

The sign of this expression will be determined by the sign of the expression in brackets. Denote $A = -(\beta^5 - 4\beta^3 + 12\beta)$ and $B = \beta^4 + 8$. Recall that $m_E(I) > m_H$ for any $I$ and thus $m_E(I) > \frac{4}{B}m_H$ if $\frac{A}{B} < 1$. Let’s check that $\frac{A}{B} < 1$. This expression is equivalent to $\beta^5 - 4\beta^3 + 12\beta - \beta^4 - 8 < 0$ that we can factorize $(\beta - 1)(\beta - 2)(\beta^3 + 2\beta^2 - 4) < 0$. It is obvious that the last inequality is always satisfied, so $\frac{A}{B} < 1$, and then that the condition (8) is strictly positive. So, the first order condition that gives $I^o$ is positive, and thus $I^* < I^o$. The condition on $\beta$ insures the existence of positive quantities. ■

This result is similar to one of the results of Bester and Petrakis (1993) for large reduction of cost, which is always satisfied here\textsuperscript{14}, and of Eswaran and Gallini (1996) in a model where they mix product and process innovation.

The entrant has less of an incentive to introduce the new product as he cannot appropriate all the social surplus. The level of investment imposed by the government is always greater than the level of investment freely chosen by the entrant. Thus, the potential entrant is always constrained to invest in a reduction of cost; this reduction is higher than the reduction he would have by maximizing his payoff.

\textsuperscript{14}Indeed, if $\Delta$ is the cost reduction of the challenger, the reduction is large if $\Delta > 2(c_E - c_H)$. This last inequality is always satisfied since $c_E - c_H < 0$. 

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The condition on $\beta$ imposes a certain degree of differentiation. If the product is differentiated enough, the potential entrant does not want to bear an important cost to reduce the production costs. Nevertheless, the differentiation is not enough from the mere social viewpoint.

In order to induce the innovator to undertake an R&D project, the patentholder requires insurance in order to have sufficient protection. This protection is such that the entrant must sufficiently reduce the marginal cost of production; that is the improvement must be sufficiently “high”. The new entrant can enter the market only if he has a product that satisfied the legal novelty requirement.

We now specify a condition for the legal novelty requirement, called simply here height$^{15}$:

$$I \text{ must be such that } \xi \leq c_H - c_E(I) \iff c_E(I) \leq c_H - \xi$$

where $\xi$ is the novelty requirement that must be satisfied for the entrant to produce his variant product. The height is a reduction in the marginal cost required of the subsequent entrant’s process relative to the patentholder. We consider that $\xi$ and $c_H$ are exogenous.

This condition determines the minimum height that must be respected; from this, the potential entrant can respect the minimum size of the innovation required. He can only enter the market with an improvement that can decrease the cost of production under a cut-off $c_H - \xi$.

Thus, there exists $I^c$ such that

$$I^c = c_E^{-1}(c_H - \xi).$$

If the potential entrant wishes to enter the market, he must spend at least $I^c$ in order to reduce his marginal cost of production.

The new regulator program is

$$\max I \frac{(\alpha - c_E(I))(\alpha - c_H)}{1 + \beta} + \frac{(c_H - c_E(I))^2}{2(1 - \beta^2)} - I \quad \text{s.t. } I \geq I^c$$

The new social optimum $I^{SO}$ that takes into account the constraint is then

$$I^{SO} = \max \{I^o, I^c\}.$$ 

Proposition 2 : The social optimal level of investment is such that $I^{SO} > I^*$. 

Proof. If $I^o > I^c$ then $I^{SO} = I^o > I^*$; if $I^o < I^c$ then $I^{SO} = I^c > I^o > I^*$. ■

The entrant still has to reduce his production costs more than he would be willing to do. This restriction does not protect the patentholder, it makes the entrant a stronger competitor.

$^{15}$We use the same definition as in Eswaran and Gallini (1996).
Indeed, the extra investment undertaken by the entrant to reduce his cost of production reduces the patentholder’s payoff\(^\text{16}\). The improvement of the total social welfare does not increase the patentholder’s payoff.

This kind of policy does not protect the patentholder even if the social welfare is enough to justify the entry. Thus, the collective welfare increases while the patentholder’s payoff decreases. This policy seems to be in contradiction with the patent system which aim is to protect the first innovator. This gives rise to the issue of how payoffs are distributed from the potential entrant to the patentholder. This problem has been pointed out several times by Scotchmer (Scotchmer (1996), Green and Scotchmer (1995)). Conceivably to avoid this result, the potential entrant should provide a transfer to the patentholder in order to recoup the R&D investment not yet recovered. However we do not address this problem. Our analysis is limited to the natural barriers to entry, namely the entry cost for the potential entrant under certain circumstances.

Recall that we have a condition on \( \beta \) that insures positive quantities. We rewrite this condition

\[
\beta < \min \left\{ \frac{m_H}{m_E(I^0)}, \frac{m_H}{m_E(I^*)} \right\}. \tag{9}
\]

We now turn to the first stage of the game, the decision stage. As a benchmark case, we consider the case in which the information is perfect: each firm knows perfectly if the demand is low or high. Then, we consider the case in which only the patentholder knows the value of the demand and decides to behave strategically in order not to reveal this value.

### 4 Perfect Nash Equilibrium

Consider the case in which both firms have the same information concerning the demand. Depending on the value of the demand (high or low), the patentholder and the potential entrant will respectively decide whether to renew or not and whether to enter or not the market. The patentholder has to pay a renewal fee \( a_H \) in order to keep her patent in force while the potential entrant has to pay an entry cost. This latter cost has two components: a real entry cost \( a_E \) and the investment needed to reduce the production costs \( I \). We assume that \( a_H \) and \( a_E \) are given while \( I \) is determined endogenously by the potential entrant. We assume that

\[
a_H < \Pi_H^H(0) - \Pi_H^H(I_i^*)
\]

\[
\Pi_E^L(I_i^0) - I_i^0 \leq a_E < \Pi_E^L(I_i^*) - I_i^*
\]

\(^{16}\)Indeed \( \frac{d\Pi_H^L(I)}{dI} < 0. \)
The assumption (10) means that the patentholder’s net monopoly payoff is always bigger than the duopoly payoff. This implies that the renewal cost is not too high. The assumption (11) means that the entry cost for the potential entrant is such that he will not enter if the innovation process is protected with a patent in the case where the demand is low. If the demand is high, the entry cost cannot prevent the potential entrant to enter the market. This entry cost represents the acquisition of machines, know-how needed to improve the original innovation. Recall that the improvement here means a reduction of the production costs which corresponds to an innovation process.

In the case of perfect information, we can state the following proposition:

**Proposition 3**: If (9), (10) and (11) are satisfied, then there exists a Perfect Nash Equilibrium such that

1. the patentholder decides to not renew her patent in case of high demand, and to renew it in case of low demand;
2. the potential entrant decides to enter if he observes a no-renewal, and to not enter otherwise.

**Proof.** By backward induction we first determine the optimal solution of the potential entrant, and then determine the optimal decision of the patentholder. When \( \alpha = \alpha_h \), the potential entrant will always choose to enter due to assumption (11). Indeed if \( a_E < \Pi_E^l(I^*_l) - I^*_l \) then \( a_E < \Pi_E^h(I^*_h) - I^*_h \). Thus, with assumption (10) the patentholder will choose not to renew her patent. When \( \alpha = \alpha_l \), the potential entrant will enter the market if the patentholder does not renew her patent because from assumption (11) \( a_E < \Pi_E^l(I^*_l) - I^*_l \). On the contrary, the potential entrant will not enter if the patentholder decides to renew her patent. The patentholder will decide to renew her patent because \( a_H < \Pi_H^l(0) - \Pi_H^l(I^*_l) \).

If the demand is low, the barrier to entry is just the entry cost. If the patent has been renewed, the potential entrant will not enter because of the entry cost: the entry cost plus the investment that the potential entrant has to incur in order to reduce the production costs are too high. Thus, in this case, the market is too narrow for two firms and thus the patentholder can deter entry if she decides to renew her patent. In fact, the choice of renewing the patent leads to two opposite effects on the profit of the potential entrant. A direct effect has a negative impact on his profit because he is forced to invest in cost reduction, whereas the strategic effect is
positive because the renewal decision decreases the quantity offered by the patentholder. Overall the direct effect is bigger than the strategic effect.

On the contrary, if the demand is high, even if the patent has been kept in force, the entry cost is not large enough to induce the potential entrant not to enter. In this case, the market is large enough for two firms to compete even though one firm holds a patent and the other firm legally enters. Thus, the patentholder who cannot deter entry, can only accommodate it and can save both the renewal cost and the reduction in payoff associated with a higher investment undertaken by the entrant. The renewal decision has also two effects (direct and strategic effects) on the profit of the patentholder, but both effects are negative and thus push her to abandon her patent.

5 Perfect Bayesian Equilibrium

We now consider the case in which the potential entrant has imperfect information concerning the demand. The concept used is the concept of Perfect Bayesian Equilibrium. We find different equilibria in pure and mixed strategies. There is no separating equilibrium in pure strategies. The patentholder will never choose a strategy that can reveal the value of the demand, but rather she will always prefer not to reveal the value of the demand. With respect to pure strategies, we find a unique Pooling equilibrium that is supported by beliefs that satisfied Cho and Kreps’ (1987) Intuitive Criterion. In mixed strategies, we find a Semi-separating equilibrium for certain values of the beliefs of the potential entrant. We first consider the equilibria in pure strategies followed by those in mixed strategies.

5.1 Pooling Equilibrium

The patentholder can decide to choose the same strategy regardless of the value of the demand. In this case the potential entrant cannot learn any information from the observation of the patentholder’s decision and his prior beliefs are equal to his posterior beliefs.

The only reasonable Pooling equilibrium is the following:

**Proposition 4**: If (9), (10) and (11) are satisfied and if the Perfect Bayesian Equilibrium outcome is supported by beliefs satisfying Cho and Kreps’ (1987) Intuitive Criterion, for \( \rho < \rho^* \), there exists a unique Pooling equilibrium in pure strategies such that

1. the patentholder decides to renew her patent whatever the value of the demand;
2. the potential entrant does not enter after observing a renewal.

Proof. See appendix. ■

In this case, if the potential entrant has low prior beliefs, and consequently low posterior beliefs too, the patentholder can decide to renew her patent and the potential entrant will decide not to enter the market. The patenting decision prevents entry because it does not give any information to the potential entrant. The patentholder signals that the demand is low, which is already supported by low prior beliefs. The renewal decision conveys the information that the demand is low and thus deters entry.

5.2 Semi-Separating Equilibrium

The patentholder can decide to choose the same action for one value of the demand and then to choose a random action for the other value of the demand. Indeed, the patentholder does not completely reveal the value of the demand by the chosen action. This equilibrium is a semi-separating equilibrium in mixed strategies and we summarize it in the following proposition:

**Proposition 5**: If (9), (10) and (11) are satisfied, and for \( \rho > \rho^* \), there exists a Semi-separating equilibrium in mixed strategies such that

1. the patentholder decides to renew her patent for low demand and randomize her decision for high demand;

2. the potential entrant decides to enter after observing a non-renewal, and to randomize his decision after observing a renewal.

Proof. See appendix. ■

The patentholder decides to always renew her patent if the demand is low, and to randomize her decision if the demand is high. The observation of the no-renewal implies that the demand is high, and thus the potential entrant enters the market. On the other hand, the observation of the renewal does not imply any information concerning the demand. So, the potential entrant also randomizes his entry decision. The likelihood of entry is thus reduced.

The patentholder makes her behavior unpredictable and thus forces the potential entrant to behave randomly. Thus, overall, the entrant will enter less often than in the symmetric case. That is why the patent can be seen as a strategic barrier to entry.
6 Conclusion

A patent is not always an effective barrier to entry as it can only restrict entry rather than preventing it. This is especially true in the case of process innovation where the entry constraint imposed by public authorities does make the entrant a stronger competitor if he can respect the novelty requirement. In our setting, it appears to be the case when the demand is high. Conversely, when the demand is low, the patent is a barrier to entry as long as the patentholder renews her patent. Our main contribution is to show that, in case of asymmetric information about the demand size, the patentholder can renew strategically her patent in order to pretend that the demand is low and to create a barrier to entry. Thus, the asymmetric information on the demand of the produced good, has an influence on the renewal strategy of the patentholder in the case of process innovation.

This outcome is highly dependent on restrictive assumptions. First we assume that the patentholder cannot reduce her own production costs. If we assume that both firms are engaged in a race, the outcome will be different. Second, we abstract from time constraint. Indeed, we do not take into account that is can take time for the entrant to invest in a reduction of production costs. Nevertheless the outcome will still be consistent with ours if we relax this assumption. Third, we assume that the patentholder is threatened just by one potential entrant. If we let several potential entrants threaten the patentholder, the results will be different.

Our focus is on process innovation, that represents one-fourth of the investment devoted to research. It will be interesting to consider a mix between process and product innovation as in Eswaran and Gallini (1996) and to see how the level of differentiation imposed on the entrant will affect the reduction of production costs and vice-versa. This extension is in our future agenda of research.
APPENDIX: Perfect Bayesian Equilibria

Proof of propositions 4, and 5.

The decision of the patentholder is whether to renew or not \( d_H : \Omega = \{\alpha_h, \alpha_l\} \to D_H = \{C, \overline{C}\} \), while the potential entrant must decide whether to enter or not \( d_E : D_H \to D_E = \{e, \overline{e}\} \).

Separating Equilibria

If firm \( H \) decides to pay the renewal fee when the market is not favorable and not to pay the renewal fee otherwise, the potential entrant knows the value of demand from the mere observation of the action undertaken by \( H \). His posterior belief \( \mu \) (on good value demand) is equal to one. Then, if firm \( E \) observes that the incumbent has paid the renewal fee, he decides not to enter the market (because the market is not favorable) and if \( E \) observes that \( H \) gives her patent up, he enters.

But, when the market is not favorable, and the firm \( E \) decides not to enter, the patentholder will deviate because

\[
\Pi^h(I^o_h) - a_H < \Pi^h(I^*_h).
\]

Then, it is not a separating equilibrium.

As it is the only possible separating equilibrium, we can conclude that there is no separating equilibrium.

Pooling Equilibria

We find two Pooling equilibria. The first is not given in the text and is summarized in the following proposition:

**Proposition 6** If (9), (10) and (11) are satisfied, there exists a Pooling equilibrium defined by

\[
d_H(\alpha) = \overline{C}, d_E(\overline{C}) = e, \forall \alpha, with an out-of-equilibrium \text{ prob}(\alpha_h/C) = 1
\]

It is interesting to notice here that this pooling equilibrium is not realistic. If we apply the intuitive criterion (Cho and Kreps (1987)), we show that this pooling equilibrium is dominated because it does not have reasonable out-of-equilibrium probability \( \text{prob}(\alpha_h/C) = 1 \).

Let’s first determine this pooling equilibrium when the incumbent decides not to pay the renewal fee regardless of the value of the market, and then apply the Intuitive criterion. The
potential entrant observes nothing and then his posterior belief is equal to his prior \( \mu = \rho \). In order to keep the proof as simple as possible, we simplify the notation: \( \Pi_{E}(.) = \Pi_{H}(.) = \Pi(.) \) with \( j = h, l \).

He decides to enter the market because \( \rho [\Pi^{h}(I_{h}^{*}) - a_{E} - I_{h}^{*}] + (1 - \rho) [\Pi^{l}(I_{l}^{*}) - I_{l}^{*} - a_{E}] > 0 \).

We now determine how the potential entrant will react if he observes that the patentholder has renewed her patent. With an out-of-equilibrium belief \( \text{prob}\{\alpha = \alpha_{h}/d_{H} = C\} = 1 \), the potential entrant will always enter. Then, the incumbent will not deviate because \( \Pi^{h}(I_{h}^{*}) > \Pi^{h}(I_{h}^{o}) - a_{H} \).

We conclude that for any values of \( \rho \), there exists a pooling equilibrium for an out-of-equilibrium belief \( \mu = \text{prob}\{\alpha = \alpha_{h}/d_{H} = C\} = 1 \) (proposition 6 above).

However this equilibrium is dominated, using the intuitive criterion (Cho and Kreps (1987)). Denote \( \Pi_{1}^{*} \) the equilibrium payoff to type \( \alpha \) in PBE. Then action \( d_{H} \) is equilibrium dominated for type \( \alpha \) in PBE \( (d_{H}^{*}(\alpha), d_{H}^{*}(\alpha), \mu) \) if \( \Pi_{1}^{*} > \max_{d_{E}} (\Pi_{1}(d_{H}, d_{H}, \alpha) \). Then we can restrict our attention to those PBEs that have reasonable beliefs. And thus, we can exclude this pooling equilibrium because \( \mu = 1 \) is not a reasonable belief.

Now, let’s determine the pooling equilibrium when the incumbent decides to pay the renewal fee whatever the value of the market. The potential entrant observes nothing and then its posterior belief is equal to its prior \( \mu = \rho \). It will decide to enter the market if

\[
\rho [\Pi^{h}(I_{h}^{o}) - a_{E} - I_{h}^{o}] + (1 - \rho) [\Pi^{l}(I_{l}^{o}) - I_{l}^{o} - a_{E}] < 0 \nonumber
\]

\[
\Leftrightarrow \rho < \frac{I_{h}^{o} + a_{E} - \Pi^{l}(I_{l}^{o})}{\Pi^{h}(I_{h}^{o}) - I_{h}^{o} - [\Pi^{l}(I_{l}^{o}) - I_{l}^{o}]} = \rho^{*}. \nonumber
\]

If the potential entrant observes that the patentholder has renewed his patent, then it will always enter, and in this case there is no interest for the patentholder to deviate. Thus, this is the unique pooling equilibrium in pure strategies for \( \rho < \rho^{*} \) (Proposition 4).

**Semi-Separating Equilibria**

Formally, the semi-separating equilibrium is the following:

If (9), (10) and (11) are satisfied, and for \( \rho > \rho^{*} \), there exists a Semi-separating equilibrium
in mixed strategies defined by

\[
\begin{align*}
    d_H(\alpha_l) &= C, \\
    d_H(\alpha_h) &= \begin{cases} 
    C & \text{with probability } q_H \\
    \mathcal{C} & \text{with probability } 1 - q_H
    \end{cases} \\
    d_E(\mathcal{C}) &= e \\
    d_E(C) &= \begin{cases} 
    e & \text{with probability } q_E \\
    \mathcal{E} & \text{with probability } 1 - q_E
    \end{cases}
\end{align*}
\]

In mixed strategies, we can derive a semi-separating equilibria. If the demand is low, the incumbent always keeps her patent in force, whereas, when the demand is high, she decides to randomize her renewal decision. She keeps her patent in force with probability \( \pi_H \), and she does not pay the renewal fee with the complementary probability \( 1 - \pi_H \).

If the strategy “abandon the patent” is observed, the value of the demand is high. Then, the entrant decides to enter the market. When the demand is high, the incumbent must be indifferent between “giving her patent up” or “keeping her patent in force”. There exists a probability \( \pi_E = \text{Prob}\{e/C\} \) such that:

\[
\pi_E[\Pi^h(0) - a_H] + (1 - \pi_E)[\Xi^h(I^o_h) - a_H] = \Pi^h(I^*_h)
\]

\[
\iff \pi_E = \frac{\Xi^h(I^o_h) - \Pi^h(I^*_h) + a_H}{\Pi^h(0) - \Pi^h(I^*_h)}.
\]

This probability exists and belong to \([0, 1] \) if

\[ a_H < \Pi^h(0) - \Pi^h(I^*_h) \]

which is satisfied.

The profit of the firm \( E \) if he enters after observing that the incumbent has kept her patent in force is:

\[
\mu(\alpha_h/C)[\Pi^h(I^o_h) - I^o_h - a_E] + [1 - \mu(\alpha_h/\mathcal{C})][\Pi^f(I^o_f) - I^o_f - a_E]
\]

whereas the profit of the entrant if he decides not to enter, when he observes that \( H \) has renewed her patent is zero.

The potential entrant must be indifferent between the decision of entry or no entry:

\[
\mu(\alpha_h/C)[\Pi^h(I^o_h) - I^o_h - a_E] + [1 - \mu(\alpha_h/\mathcal{C})][\Pi^f(I^o_f) - I^o_f - a_E] = 0
\]

\[
\mu(\alpha_h/C) = \frac{a_E + I^o_f - \Pi^f(I^o_f)}{\Pi^h(I^o_h) - I^o_h - (\Pi^f(I^o_f) - I^o_f)}. \tag{12}
\]
By definition
\[ \mu(\alpha_h/C) = \frac{\pi_H(C/\alpha_h)\rho}{\pi_H(C/\alpha_h)\rho + \pi_H(C/\alpha_h)(1 - \rho)} = \frac{\rho\pi_H}{\rho\pi_H + (1 - \rho)}. \] (13)

We can substitute (13) in (12) and then:
\[ \frac{\rho\pi_H}{\rho\pi_H + (1 - \rho)} = \frac{a_E + I_{\ell}^o - \Pi^f(I_{\ell}^o)}{\Pi^h(I_{\ell}^o) - I_{\ell}^o - (\Pi^f(I_{\ell}^o) - I_{\ell}^o)} \]
\[ \iff \pi_H = \frac{1 - \rho}{\rho} \frac{a_E + I_{\ell}^o - \Pi^f(I_{\ell}^o)}{\Pi^h(\beta(I_{\ell}^o)) - I_{\ell}^o - a_H}. \]

As \( \rho \in ]0,1[ \) and \( \pi_H \) must be smaller than 1 we obtain
\[ \pi_H < 1 \iff (1 - \rho)(a_E + I_{\ell}^o - \Pi^f(I_{\ell}^o)) < \rho[\Pi^h(\beta(I_{\ell}^o)) - I_{\ell}^o - a_H] \]
\[ \iff \rho > \rho^*. \]

We have demonstrated that for \( \rho > \rho^* \), and if \( a_H > \Pi^h(I_{\ell}^o) - I_{\ell}^o \), there exists a semi-separating equilibrium which is, for the incumbent, to give her patent up when the market is favorable, and to randomize her renewal decision when the market is not favorable.

The potential entrant decides not to enter the market if he observes that the incumbent has not kept her patent in force, as he knows that the market is not favorable for entry. But, when he observes that the patentholder pays the renewal fee, he randomizes his entry decision, as he cannot infer any information.
References


