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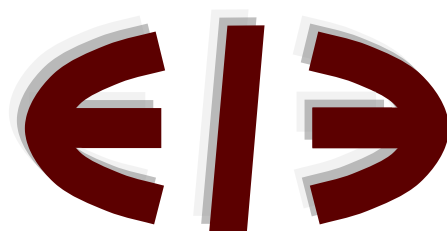
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Patent Protection and Threat of Litigation in Oligopoly

Carlo Capuano* and Iacopo Grassi†

Abstract

In recent years, the increasing awarding of patents has captured the attention of scholars operating in different fields. Economic literature has studied the causes of this proliferation; we propose an entry game focusing on one of the consequences, showing how an incumbent may create a patent portfolio in order to control market entry and to collude. The incumbent fixes the level of patent protection and the threat of denunciation reduces the entrant's expected profits; moreover, if the entrant deviates from collusion, the incumbent can strengthen punishment suing the competitor for patent infringement, reducing her incentive to deviate. Our analysis suggests that antitrust authorities should pay attention to the level of patent protection implemented by the incumbent and note whether the holder of a patent reacts to entry by either suing or not suing the competitor. In the model, we use completely general functional forms in analyzing the issues, and this allows us to obtain general results not depending on the assumptions about the kind of oligopolistic competition.

Keywords: patents, patent portfolio, litigation, collusion, foreclosing, entry game

JEL Code: D43, K21, L13

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1 Introduction

In recent years, the huge proliferation in patenting has captured the attention of scholars operating in different fields: for example, Boldrin and Levine (2013) note that 'In 1983 in the United States, 59,715 patents were issued; by 2003, 189,597 patents were issued; and in 2010, 244,341 new patents were approved. In less than 30 years, the flow of patents more than quadrupled'. It is interesting to note that patents have grown more than R&D spending,¹ increasing the patent intensity, i.e. the ratio between number of patents and R&D expenditure, and that firms in most industries do not rely on patents to profit from R&D investments.²

Such increase in the number of patents has caused an explosion of patent litigation in many industries: the Price Waterhouse Cooper 2014 Litigation Study,³ based on US Patent and Trademark Office Data, reports an annual 8% growth in patent actions filed from 1991 through 2013.⁴ However, the growth in the number of litigations is lower than the growth in the number of patents: Lemley (2001) estimates that only 0.1 percent of all patents are litigated to trial. Moreover, Kesan and Ball (2010) state that patent litigation is a settlement mechanism: about 10 percent of patent cases filed in 2000 led to rulings and verdicts; more recently, Allison et al. (2014) present a study of patent litigation filed in US Federal Courts in 2008 and 2009 (roughly 5000 lawsuits): it emerges that less than 20% arrives to a verdict. In other words, with respect to the huge number of patents granted every year, few are litigated, even less arrive to a verdict.

These evidences (patent paradox, relative few litigations and verdicts) may undermine the idea that firms patent to protect innovation, and suggest that patents have a different role in the strategy of the firm. Economic literature has given some explanations concerning such a role: one is that patents serve as a quality signal for markets and investors;⁵

¹See Blind et al. (2006).

²This is the so called *patent paradox*. See Hall and Ziedonis (2001), Shrestha (2010) and Pénin (2012).

³Available on line at <http://www.pwc.com/us/en/forensic-services/publications/patent-litigation-study.html>

⁴Probably, some of the most famous of these lawsuits are the ones between Apple Inc. and Samsung Corp. in the so-called smartphone patent war, but there were similar cases in many other industries: in 1999, a patent for one-click ordering technology led to a patent war between Amazon.com and Barnes & Noble; in 2004, Sony and Kodak engaged in a patent war over digital cameras; in 2009, Stretchline sued H&M for infringing bra patent; in recent years, the agricultural giant Monsanto sued hundreds of small farmers in the United States in attempt to protect its patent rights on genetically engineered seeds; in 2014, Bose sued Beats over patents on noise-canceling headphones etc.

⁵See, inter alia, Long (2002), Gambardella (2013), Comino and Graziano (2015).

another is that firms may build a patent portfolio as a defensive tool in a lawsuit for patent infringement;⁶ some literature has analyzed abuses of single dominant position by the owner of a patent portfolio finalized to maintain a monopolistic position.⁷

In our analysis we do not neglect these reasons, but we look at the problem from an ex-post perspective, considering a consequence of patent granting: we present a model where creating a patent portfolio can be finalized to control market entry and to collude. To the best of our knowledge, there is no literature on the relation between building a patent portfolio and colluding.⁸

We propose an entry game where an incumbent protects her market with patents. However, patents do not grant *per se* a monopoly, since they may be invalidated by a court;⁹ hence, another firm may enter the market and compete. As in Yiannaka and Fulton (2011), the key idea presented in our paper is that the value of a patent lies in the *option* that it creates to litigate.¹⁰ We show that patents facilitate collusion, because the threat of denunciation reduces the entrant expected profits, and, if the entrant deviates from collusion, the incumbent can strengthen punishment suing her for patent right infringement. The consequence is that the incumbent may use her patent portfolio in order to relax competition in the market making collusion easier to sustain. The main result of the paper is that the incumbent might find it optimal to collude with the entrant when the lawsuit cost is low enough and the cost for implementing patent protection is high enough.

In addition, note that, since we use completely general functional forms in analyzing the issues, our results are very general and not affected by arbitrary assumptions about the kind of oligopolistic competition, or the level of product differentiation.

A relevant policy implication of our analysis is that enforcing patent

⁶See Hall and Ziedonis (2001), Ziedonis (2004), Choi and Gerlach (2017).

⁷Analysis of deterrence to entry through the refuse of licensing or the threat of sue for patents infringement are in Lerner and Tirole (2004), Robledo (2005), Agarwal et al. (2009), Gavin and Toh (2010). See Somaya (2012) for a survey of the literature on the strategic use of patents.

⁸A branch of the literature analyzes how, in an entry game, a firm that obtained a patent may find it optimal not to sue the entrant: see, for example, Choi (1998), Aoki and Hu (1999), Yiannaka and Fulton (2006).

⁹Patent protection is always stochastic and in some cases may be *weak*: on the notion of probabilistic patents see Lemley and Shapiro (2005); on the notion of weak patents see Farrell and Shapiro (2008).

¹⁰However, they present an entry game focused on the effect that potential litigation has on the quality differentiation between goods while we consider a general framework, underlining how this option modifies the trigger strategy of the incumbent.

protection can be part of a pro-collusive strategy by firms with significant market power abusing their dominant position, in violation of Article 102 of the Treaty of Functioning of the European Union (TFEU). Under the US antitrust law, we have a facilitating practice, patenting without invoking a trial to defend the market from entry, that sustains a price-fixing scheme; the latter is a per se violations of Section 1 of the Sherman Act.

The paper is organized as follows: in Section 2 we briefly recall the framework we use to analyze collusion sustainability; in Section 3 we present the model and analyze the subgame perfect Nash equilibria (SPNE) of the game, focusing on the case where collusion emerges as an equilibrium; policy implications and conclusions are discussed in Section 4.

2 Tacit collusion in oligopoly

Tacit collusion is a strategic conduct that enables firms to obtain supra-normal profits, where normal profits correspond to the ones achieved in the one shot game equilibrium. The analysis of collusion is based on the so called *incentive compatible constraint* for collusion: collusion is sustainable if there are not incentives to defect, which requires the expected benefits from collusion to be higher than the expected benefits from deviation.

In general, collusion is more likely to arise when deviating firm would obtain small gains from deviation, when punishment does affect her payoff and when each firm attaches high weight to future profits. The latter depends on the value of the firm's discount factor of the future profits (usually indicated for firm i with the symbol δ_i).

Following Friedman (1971), let N , C and D be respectively the one-shot payoffs in the Nash equilibrium, in case of collusion and in case of deviation from collusion, where $D > C > N$. Considering supergames, i.e. infinitely repeated one-shot games, according to the given trigger strategy,¹¹ in order to sustain collusion the following incentive compatible constraint must be satisfied.

$$\frac{C}{1 - \delta_i} \geq D + \frac{\delta_i N}{1 - \delta_i} \quad (1)$$

That is

¹¹A grim trigger strategy is any of a class of strategies in which a player begins by cooperating in the first period, and continues to cooperate until a single defection by the opponent is observed. If defection occurs the player using grim trigger will play Nash reversion for the remainder of the iterated game. This strategy is applied to infinitely repeated games.

$$\delta_i \geq \sigma^* = \frac{D - C}{D - N} \quad (2)$$

where δ_i is the individual discount factor of firm i , measuring the weight of future profits, and σ^* is the critical discount factor. Constraint (1) compares expected profits by collusion with the ones by deviation in an infinite-horizon setting. According to (2), only if each firm is sufficiently patient, i.e. $\forall i, \delta_i \geq \sigma^*$, tacit collusion is part of a SPNE of the considered game.

The higher the value of σ^* , the more difficult the sustainability of collusion.¹² This argument can be applied to every kind of oligopolistic market.¹³

3 The model

3.1 Model setting

We consider a market where initially only one firm, the incumbent I , operates protecting her monopoly with a patent portfolio. The incumbent enforces the wished level of patent protection registering the chosen number of patents; in particular, we assume: stochastic patent protection;¹⁴ positive correlation between probability of succeeding in patent litigation and size of patent portfolio; not negligible cost for implementing patent protection. In other words, in order to enforce a probability of succeeding in a patent litigation equal to $\beta \in [0, 1]$, the incumbent bears a cost $x(\beta) > 0$. The cost function $x(\beta)$ is increasing and convex with respect to β , and such that the incumbent earns negative expected profits by enforcing a probability of success $\beta = 1$. This assumption avoids deterministic (or complete) patent protection.¹⁵

When a competitor E enters the market, the incumbent can sue the entrant for patent right infringement; at the same time, the entrant may ask the court to invalidate the patent.¹⁶ In case of lawsuit, the incumbent and the entrant sustain an additional cost $L > 0$ regardless

¹²For example, it is easy to show that, in a duopoly with linear demand and constant marginal costs, collusion is easier to sustain under price competition ($\sigma^* = 0.5$) than under quantity competition ($\sigma^* \simeq 0.53$).

¹³It is easy to check the robustness of our results assuming different punishment mechanisms, such as optimal penal code, that impact only the value of the critical discount factor.

¹⁴See Lemley and Shapiro (2005).

¹⁵We assume that $x(0) = 0$, $x' > 0$, $x'' > 0$ and $x(1) \gg \frac{M}{1-\delta_I}$, where M and δ_I respectively denote the one-shot monopolistic profit and the incumbent's discount factor.

¹⁶Note that, independently from the firm starting the trial, the probability to have a judgement in favor of the incumbent (entrant) is always $\beta(1-\beta)$.

the outcome of the process. In order to avoid the trivial case where too high lawsuit costs disincentivize firms to litigate, we restrict our attention to values of L low enough. Moreover, we assume that, under a legal patent protection system, none can be tried two times for the same violation. In order to stress the strategic role of patenting in the entry game, we assume the existence of only one potential entrant and rule out the possibility of licensing.

If the incumbent wins the trial, a fine $F > 0$ is charged to the entrant and transferred to the incumbent; the entrant goes out from the market. Conversely, if the decision is in favor of the entrant, no fine is charged and firms compete in a duopolistic market.

The game is specified as follows:

- At the pre-entry stage $t=0$, the incumbent chooses the number of patents to protect the market: this implements an endogenous probability β of success in a lawsuit for patent right infringement.

- At stage $t=1$, the entrant observes β and decides whether to enter the market and compete with the incumbent.¹⁷

- At stage $t=2$ (with the entry of a competitor), both firms can start a lawsuit: the incumbent may sue the entrant for patent right infringement; the entrant may ask the court to invalidate the patents.

- At stage $t=3$, if any firm had sued the competitor, a court (nature) decides the lawsuit outcome. If the judgment is in favour of the incumbent (with probability β), the entrant pays a fine F to the incumbent, and exits the market; otherwise (with probability $1 - \beta$), the two firms stay in the market.

- At stage $t=4$, firms start market competition according to the outcomes of previous stages. This stage is infinitely repeated.

Figure 1 describes the timing of the game.

In the production stage ($t=4$), we observe monopoly either if at $t=1$ entry does not occur, or if at $t=3$ the court's judgement is in favor of the incumbent; we observe duopoly either if at $t=2$ none have started the lawsuit, or if at $t=3$ the court's judgement is in favor of the entrant.¹⁸

¹⁷If $\beta = 0$, the competitor always enters the market and collusion is sustainable if firms are sufficiently patient.

¹⁸Note that collusion may emerge in equilibrium only when entry occurs and none sues the competitor: firms cannot collude after the court decides in favor of the entrant. This is not an assumption, but an implicit result of our model setting: at this stage of the game lawsuit and patent registration are sunk costs, hence the one-period profits and the critical discount factors needed to collude are unaffected by the court decision; then, if collusion is not sustainable at the beginning of the game, it will not be even at this stage. In other words, firms patient enough to collude at $t=4$, can collude at $t=0$ as well, without incurring in patents and lawsuits costs: colluding at $t=0$ strictly dominates colluding at $t=4$.

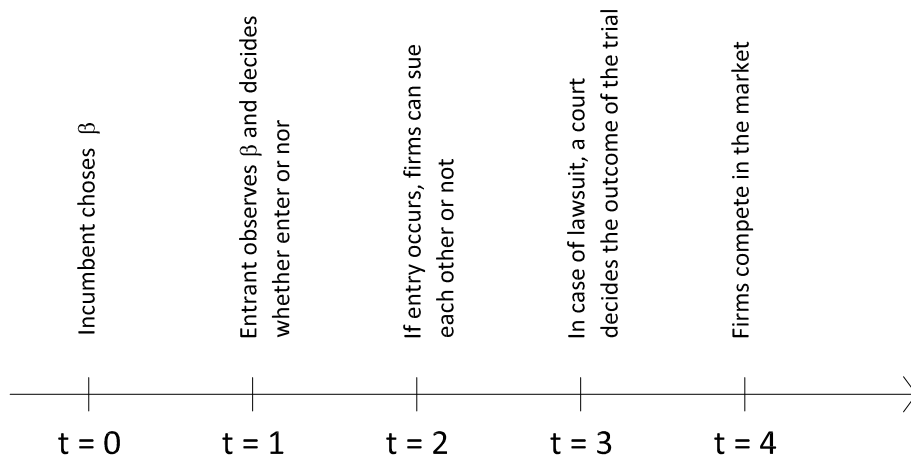


Figure 1: The timing of the game

In all stages, firms play non-cooperatively and simultaneously. Moreover we assume symmetry in the firm's one-shot profits by collusion, deviation and Nash competition (i.e. $C_E = C_I = C$, $D_E = D_I = D$ and $N_E = N_I = N$, where $D > C > N \geq 0$), asymmetry in the firms' discount factors (i.e. $\delta_E \stackrel{\geq}{\leq} \delta_I$), and discounted profits from the repetition of the production stage.¹⁹ We use backward induction to find the SPNE of the game.

Setting the level of patent protection (β) is the core of the incumbent's strategies: she can choose either a *non-cooperative* strategy (*nc*), an aggressive strategy of *full deterrence* (*fd*), or an accommodating strategy of *collusion* (*ac*). In case of non-cooperative strategy, the incumbent maximizes her non-collusive expected profits aware of the potential en-

¹⁹Despite the finite duration of patent protection, our model assumes an infinite horizon. What may seem like an unrealistic hypothesis does not invalidate the insight of our analysis. As explained by Tirole (1988), '*the infinite horizon assumption needs not to be taken too seriously*' (p. 253). Even if patent protection is limited to a finite number of periods we may assume that at each period there is a probability that the market does not survive (for example that an innovative good is produced), hence the game '*ends in finite time but everything is as if the horizon is infinite*'. The σ represents the firm expectation on the market length.

try of a new competitor; in case of full deterrence, she implements the level of patent protection that makes entrant's expected profit non positive; in case of collusion, she accommodates the entry not suing the entrant and setting the collusive outcome. At the same time the entrant can either enter the market asking the court to invalidate the patents or competing without suing the incumbent; in this case collusion may emerge as equilibrium of the game.

We now discuss the incumbent's strategies and the equilibria in the subgames.

3.2 Non-collusive entry (nc)

We start considering the non-collusive subgame. We assume that, bearing a cost $x(\beta)$, the incumbent sets a β such that her expected profit is maximized.

If $\beta > 0$, when entry occurs both firms can start a lawsuit, paying a cost $L > 0$. In case of patent infringement (with probability β), the entrant pays a fine $F > 0$ and exits the market, while the incumbent remains monopolist. Otherwise (with probability $1 - \beta$), the two firms play a one-shot Nash equilibrium at any production stage. Firms discount profit at δ_i with $i = E, I$. Hence, the firms' expected profits, independently from the firm starting the trial, are the following:

$$\Pi_E^{nc} = \beta(-F) + (1 - \beta) \left(\frac{N}{1 - \delta_E} \right) - L \quad (3)$$

$$\Pi_I^{nc} = \beta \left(\frac{M}{1 - \delta_I} + F \right) + (1 - \beta) \left(\frac{N}{1 - \delta_I} \right) - x(\beta) - L \quad (4)$$

where:

E and I denote the entrant and the incumbent;

Π_E and Π_I are the entrant's and the incumbent's expected profits;

nc is the index denoting the non-cooperative case;

$\beta \in [0, 1]$ is the incumbent's probability of success in lawsuit (i.e. the level of enforced patent protection);

$x(\beta)$ is the cost of implementing a level of patent protection equal to β ;

L is the fixed cost of standing trial;

F is the fine charged to the entrant and transferred to the incumbent when the court finds an infringement;

M is the one-shot monopoly profit;

N is the per-firm one-shot Nash profit in duopoly;

δ_E and δ_I are respectively the entrant's and the incumbent's discount factors.

In order to have a framework as general as possible, we assume that: $M > N \geq 0$, $\delta_E \in [0, 1)$, $\delta_I \in [0, 1)$, all the relevant parameters are common knowledge and the firms' discount factors are observable.

In this case, the incumbent sets β equal to the level β^{nc} such that her expected profit is maximized, that is:

$$\beta^{nc} = \arg \text{Max} \Pi_I^{nc}(\beta)$$

Maximizing with respect to β the profit expressed by condition (4), we have:

$$\frac{M - N}{1 - \delta_I} + F = x'(\beta^{nc})$$

Notice that, β^{nc} is unaffected by the cost of standing trial L and decreasing with respect to the cost of implementing patent protection, $x(\beta)$ (which is assumed increasing in β).

3.3 Full deterrence (fd)

In case of full deterrence, the incumbent sets a β such that the entrant's expected profit, described in equation (3), is equal to zero: the competitor does not enter the market and the incumbent keeps her monopoly.

When we exclude any patent protection (i.e. $\beta = 0$) entry always occurs, since the entrant's expected profit $\Pi_E^{nc}(\beta = 0)$ is strictly positive.

However, there exists a threshold value of the level of patent protection $\beta^{fd} \in [0, 1]$ implemented by the incumbent, such that for higher values of β entry is not profitable without collusion. If we set the entrant's expected profit computed in equation (3) to zero, we obtain:

$$\beta^{fd} = \frac{N - L(1 - \delta_E)}{N + F(1 - \delta_E)} \quad (5)$$

Hence, if $\beta \geq \beta^{fd}$, the incumbent deters entry obtaining the following profit:²⁰

$$\Pi_I^{fd} = \Pi_I^{nc}(\beta^{fd}) = \frac{M}{1 - \delta_I} - x(\beta^{fd}) \quad (6)$$

Notice that, β^{fd} is unaffected by the cost of implementing patent protection $x(\beta)$ and decreasing with respect to the cost of standing trial L .²¹

²⁰This conduct may represent a strategic barrier to entry.

²¹If $\beta^{nc} \geq \beta^{fd}$, the full deterrence strategy dominates the non-collusive one and the incumbent sets $\beta = \beta^{fd}$.

3.4 Accommodation and collusion (ac)

In the accommodating subgame, the incumbent sets a β such that collusion is sustainable. When collusion emerges in equilibrium, no firm starts the trial and both produce the collusive outcome. The profits are the following:

$$\Pi_E^{ac} = \frac{C}{1 - \delta_E} \quad (7)$$

$$\Pi_I^{ac} = \frac{C}{1 - \delta_I} - x(\beta) \quad (8)$$

where C is the per-firm one-shot profit in case of collusion and the apex ac denotes the collusive case.

In our framework collusion can emerge as equilibrium in two different cases.

The first case occurs when firms are sufficiently patient to collude even though no patent protection is implemented at stage $t=0$. According to Friedman (1971), this happens when:

$$\delta_I \geq \sigma_I(\beta = 0) = \frac{D - C}{D - N} \quad (9)$$

$$\delta_E \geq \sigma_E(\beta = 0) = \frac{D - C}{D - N} \quad (10)$$

where D is the one-shot deviation profit and $\sigma_I(\beta = 0)$ and $\sigma_E(\beta = 0)$ are the incumbent's and the entrant's critical discount factors when $\beta = 0$.²² Hereafter we denote by $\sigma_I(0)$ and $\sigma_E(0)$ the critical discount factors when $\beta = 0$ and by $\sigma_I(\beta)$ and $\sigma_E(\beta)$ the critical discount factors when $\beta > 0$.

The second case occurs when condition (9) or (10) (or both) is not satisfied at $\beta = 0$ and the incumbent implements a positive level of patent protection (i.e. $\beta > 0$).

In this case firms play the following *modified grim trigger strategy*:

- when the new competitor enters the market no firm goes to court and they collude in the first production stage;

- in the following repetitions any firm observes the behavior of the competitor in the previous stage. If both firms played collusively, each

²²Notice that, in $\beta = 0$, $\sigma_I = \sigma_E = \frac{D-C}{D-N}$.

firm continues to collude; if a deviation occurred, Nash reversion is implemented as punishment. Furthermore, each firm sues the rival.

This collusive equilibrium requires that no firm goes to court and no firm has a positive unilateral incentive to deviate from the collusive production outcome.

Consider first the entrant's incentive to deviate from collusion: she may deviate from collusion either at $t=2$ or at $t=3$. When the entrant deviates at $t=2$, she sues the incumbent and her expected profit, Π_E^{nc} , is the one described in equation (3). When the entrant deviates at $t=3$ in the production stage, she cheats the incumbent and goes to the court, her expected profit, Π_E^{dev} , is the following:

$$\Pi_E^{dev} = (D - L) + \beta(-F) + (1 - \beta) \left(N \left(\frac{\delta_E}{1 - \delta_E} \right) \right) \quad (11)$$

where the apex *dev* identifies the deviation case.²³

In order to boost the entrant to collude, three constraints must be fulfilled: one participation constraint, $\Pi_E^{ac} \geq 0$, and two incentive compatible constraints, $\Pi_E^{ac} \geq \Pi_E^{nc}$ and $\Pi_E^{ac} \geq \Pi_E^{dev}$. It is trivial to show that, for any $\beta > 0$, $\Pi_E^{nc} < \Pi_E^{dev}$, and the second incentive compatible constraint dominates the first one. Hence, the entrant's incentive compatible constraint making collusion sustainable is the following:

$$\frac{C}{1 - \delta_E} \geq (D - L) + \beta(-F) + \left(\delta_E \left(\frac{N(1 - \beta)}{1 - \delta_E} \right) \right) \quad (12)$$

From which we obtain:

$$\delta_E \geq \sigma_E(\beta) = \frac{(D - L) - F\beta - C}{(D - L) - N + \beta(N - F)} \quad (13)$$

There is a threshold value of the entrant's discount factor, $\sigma_E(\beta)$, making the constrain (12) satisfied as an equality. Consequently, the collusive strategy is part of a SPNE only if the entrant's discount factor, δ_E , is not smaller than $\sigma_E(\beta)$.

It is easy to check that increasing either the level of patent protection, the legal cost of a trial or the fine for violation (i.e. increasing respectively β , L or F), decreases the entrant's critical discount factor, $\sigma_E(\beta)$, making collusion easier to sustain.

²³As usual, we assume that $D > C > N$ and $L, F < N$. Moreover, we set D such that the for any $\beta \in [0, 1]$, $(D - L) - C + \beta(-F) > 0$; this avoids the trivial case where collusion is sustainable for any $\delta_E \geq 0$.

Consider now the incumbent's incentive to deviate from collusion.

Deviating from collusion, the incumbent defects the tacit agreement on production and sues the entrant for patent right infringement. This is profitable only if the cost of a trial is smaller than the associated expected benefit, i.e. if $L \leq \beta \left(F + \delta_I \frac{M-N}{1-\delta_I} \right)$.²⁴

In such a case the profit of deviation is:

$$\Pi_I^{Dev}(\beta) = D + \beta \left(F + \delta_I \frac{M}{1-\delta_I} \right) + (1-\beta) \frac{\delta_I}{1-\delta_I} N - x(\beta) - L \quad (14)$$

We set D such that, for any $\beta \in [0, 1]$, $(D - L) - C + \beta(F) > 0$.²⁵

The incumbent's incentive compatible constrain, $\Pi_I^{Coll}(\beta) \geq \Pi_I^{Dev}(\beta)$, is now:

$$\frac{C}{1-\delta_I} \geq D - L + \beta \left(F + \delta_I \frac{M}{1-\delta_I} \right) + (1-\beta) \left(\frac{\delta_I}{1-\delta_I} N \right) \quad (15)$$

From which we obtain:

$$\delta_I > \sigma_I(\beta) = \frac{(D - L) - C + F\beta}{(D - L) - N - \beta(M - N - F)} \quad (16)$$

Also in this case, there is a threshold value of the incumbent's discount factor ($\sigma_I(\beta)$) making the constrain (15) satisfied as an equality. Consequently, the collusive strategy is part of a SPNE only if the entrant's discount factor, δ_I , is not smaller than $\sigma_I(\beta)$.

Notice that, increasing either the level of patent protection (β) or the fine (F) increases the incumbent's critical discount factor ($\sigma_I(\beta)$), making collusion harder to sustain. Conversely, increasing the legal cost of a trial (L) decreases the incumbent's critical discount factor making collusion easier to sustain.

For simplicity of notation, hereafter we use $\sigma(0)$ and $\sigma(0^+)$ instead of $\sigma_E(0) = \sigma_I(0)$ and $\sigma_E(0^+) = \sigma_I(0^+)$. Figure 2 represents the incumbent's and the entrant's critical discount factors as functions of the

²⁴Notice that when $L > \beta \left(F + \delta_I \frac{M-N}{1-\delta_I} \right)$, the incumbent does not sue the competitor and her expected profit by deviation becomes $D + \delta_I \frac{N}{1-\delta_I}$ as in the case where $\beta = 0$.

²⁵Analogously to the entrant's case, this assumption avoids the trivial case where collusion is sustainable for any $\delta_I \geq 0$.

level of patent protection β enforced by the incumbent. The horizontal dotted line represents the critical discount factor when $\beta = 0$ (no patent protection): in this case, the incumbent's and the entrant's critical discount factors are equal. In $\beta = 0^+$, we observe the same downward jump for both the critical discount factors; after that, when $\beta > 0$, the decreasing continuous line represents $\sigma_E(\beta)$ and the increasing dotted line describes $\sigma_I(\beta)$.

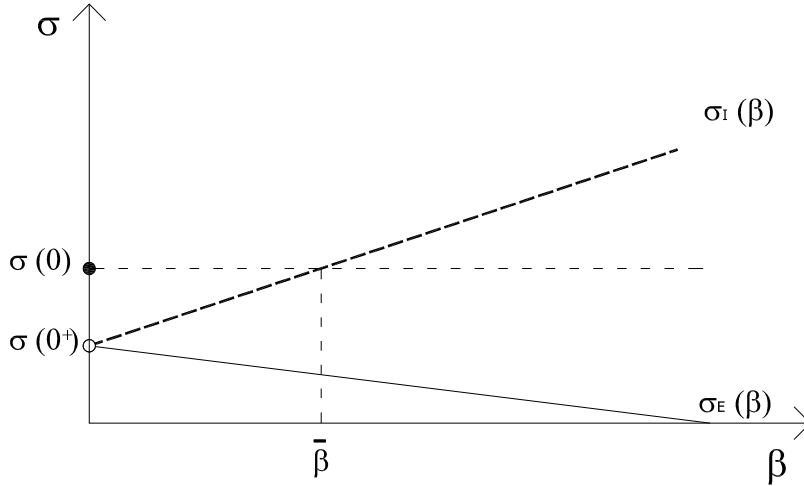


Figure 2: The critical discount factors

The analysis of Figure 2 allows us to state the following Proposition:

Proposition 1 *Denoting by $\bar{\beta}$ the positive level of patent protection such that $\sigma_I(\bar{\beta}) = \sigma(0)$, we have that:*

- *If $\beta \leq \bar{\beta}$, then $\sigma_E(\beta) \leq \sigma(0)$ and $\sigma_I(\beta) \leq \sigma(0)$;*
- *If $\beta > \bar{\beta}$, then $\sigma_E(\beta) \leq \sigma(0)$ but $\sigma_I(\beta) > \sigma(0)$.*

Proof. When $\beta = 0$, a marginal increase in β has a negative and discrete impact equal to L on the expected deviation gains of both the firms. This creates a discontinuity and a downward jump in the discount factors. Any additional increase in the level of patent protection has a different impact on the entrant's and the incumbent's deviation profits, and hence on the critical discount factors: the entrant's critical discount factor is decreasing, since increasing β raises the expected fine to be paid reducing her deviation profits. For the incumbent we have the reverse:

her critical discount factor is increasing, since increasing β raises the expected fine to be received. Until the threshold values $\bar{\beta}$, increasing β implements levels of critical discount factors smaller than the ones computed in the case of no patent protection. According to Figure 2, for levels of β higher than $\bar{\beta}$, $\sigma_E(\beta)$ continues to decrease, while $\sigma_I(\beta)$ is higher than $\sigma(0)$. ■

From the previous Proposition we obtain the following result:

Result 1 *If $\beta < \bar{\beta}$, increasing patent protection facilitates collusion; if $\beta \geq \bar{\beta}$, increasing patent protection facilitates collusion only if the incumbent is sufficiently patient*

If $\beta < \bar{\beta}$, both critical discount factors are smaller than the ones in the no patent protection case ($\beta = 0$), hence collusion is easier. If $\beta \geq \bar{\beta}$, the critical discount factor of the entrant continues to be smaller while the incumbent's one is higher than the ones obtained for $\beta = 0$, hence a *patient* incumbent (a firm with a very high δ_i) may increase patent protection in order to induce an *impatient* entrant to collude.

In both cases the level of patent protection is a strategic tool in the hands of the incumbent, affecting collusion sustainability.

3.5 Collusion sustainability

In this class of models, the incumbent and the entrant have an individual discount factor (respectively δ_I and δ_E) measuring their intertemporal preferences: a firm with high level of δ_i is a *patient* firm, placing greater weight on future profits. In the previous sections we computed the critical discount factors, $\sigma_I(\beta)$ and $\sigma_E(\beta)$ as a function of the level of β implemented by the incumbent. In Figure 2, we drawn the critical discount factors of the incumbent and the entrant as function of β .

Analyzing the graph we can obtain the necessary conditions for collusion sustainability:

Proposition 2 *If $\tilde{\beta}_i$ is the value of β such that $\sigma_i(\beta) = \delta_i$ (where $i = I, E$), necessary conditions for collusion sustainability in the accommodating subgame are:*

- (a) $\delta_I \geq \sigma(0^+)$;
- (b) $\tilde{\beta}_I \geq \tilde{\beta}_E$ only if $\delta_E < \sigma(0^+)$.

Proof. (a) Collusion is sustainable if and only if, for each firm, the individual discount factor is not smaller than her critical one. Since $\sigma_I(\beta)$ is increasing in β and $\sigma(0^+)$, is the minimum value of the function $\sigma_I(\beta)$, if $\delta_I < \sigma(0^+)$, collusion cannot be sustainable by definition, hence

we must have $\delta_I \geq \sigma(0^+)$. (b) Compare now the two firms discount factors, δ_I and δ_E . We have two possible cases. In the first case the incumbent is the less patient, i.e. $\delta_E > \delta_I$: if $\delta_I < \sigma(0^+)$ collusion cannot be sustainable; if $\delta_I \geq \sigma(0)$, we have two patient firms and collusion is sustainable at $\beta = 0$; if $\sigma(0^+) \leq \delta_I < \sigma(0)$ collusion is sustainable at $\beta = 0^+$. In the second case the entrant is the less patient, i.e. $\delta_I \geq \delta_E$. Analogously to the previous case, if $\delta_E \geq \sigma(0)$, we have two patient firms and collusion may be sustainable at $\beta = 0$; if $\sigma(0^+) \leq \delta_E < \sigma(0)$ collusion may be sustainable at $\beta = 0^+$. x Finally, if $\tilde{\beta}_I \geq \tilde{\beta}_E$ collusion is sustainable when $\beta = \tilde{\beta}_E$. ■

Figure 3 illustrates the relevant case where $\delta_E < \sigma(0^+)$ and $\delta_I > \sigma(0^+)$: in this case collusion is sustainable with $\beta > 0$.

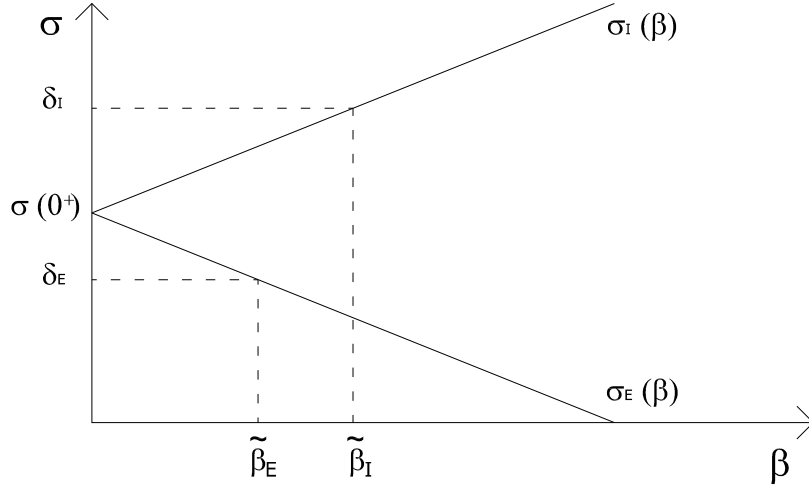


Figure 3: The case where collusion is sustainable with $\beta > 0$

Considering the complete game, we obtain the following result:

Result 2 *The collusive equilibrium is sustainable if and only if:*

(a) *the incumbent implements levels of patent protection equal to:*

1. $\beta^{ac} = 0$ when $\delta_E \geq \sigma(0)$ and $\delta_I \geq \sigma(0)$
2. $\beta^{ac} = 0^+$ when $\delta_E \geq \sigma(0^+)$, $\delta_I \geq \sigma(0^+)$ and $\min[\delta_E, \delta_I] < \sigma(0)$

3. $\beta^{ac} = \tilde{\beta}_E$ when $\delta_E < \sigma(0^+)$, $\delta_I \geq \sigma(0^+)$ and $\tilde{\beta}_I \geq \tilde{\beta}_E$

(b) collusion maximizes the incumbent's expected profit, i.e. $\Pi_I^{ac}(\beta_I^{ac}) \geq \text{MAX} [\Pi_I^{nc}(\beta^{nc}), \Pi_I^{fd}(\beta^{fd}), 0]$.

The previous result shows the amount of patent protection the incumbent may set to facilitate collusion with the entrant. This amount may tend to zero; nevertheless, some cases exist where the equilibrium of the game is given by $\beta > 0$.

When both firms are very patient (i.e. $\delta_E, \delta_i \geq \sigma(0)$), collusion is sustainable even though the incumbent does not invest in patent protection. Since implementing patent protection is costly, the optimal level of patent protection is $\beta^{ac} = 0$.

When both firms are moderately patient (i.e. their discount factors are not smaller than $\sigma(0^+)$ and at least one of the two is smaller than $\sigma(0)$), implementing an infinitesimal level of patent protection $\beta^{ac} = 0^+$ makes collusion sustainable. Such a level is sufficient to give the incumbent the possibility of suing the entrant in case of deviation: both firms bears the lawsuit cost L reducing their critical discount factors to $\sigma(0^+) < \sigma(0)$.

When the incumbent is at least moderately patient but the entrant is not (i.e. $\delta_E \geq \sigma(0^+)$ and $\delta_I < \sigma(0^+)$), the optimal level of patent protection is $\beta^{ac} = \tilde{\beta}_E$. Starting from $\beta = 0^+$, increasing β reduces the entrant's discount factor while increases the incumbent's one. At $\beta = \tilde{\beta}_E$, the entrant has not unilateral incentives to deviate from collusion (i.e. $\sigma_E(\tilde{\beta}_E) = \delta_E$); if neither the incumbent has incentives to deviate (i.e. if $\sigma_I(\tilde{\beta}_E) \leq \delta_I$) collusion is sustainable in equilibrium. The latter condition is satisfied if and only if $\tilde{\beta}_I \geq \tilde{\beta}_E$.

Under which conditions is the collusive profit the highest? The lawsuit cost (L) and the cost for enforcing patent protection ($x(\beta)$) affect the equilibria of the game. It is easy to check that for lawsuit costs high enough, full deterrence emerges as an equilibrium, since a low level of patent protection is sufficient to reduce to zero the entrant's expected profits; in other words, the incumbent remains monopolist with a very low investment in patents. On the contrary, when the lawsuits costs are low enough, full deterrence requires a larger investment; this may not be profitable, hence incumbent may prefer an alternative strategy. If the cost for implementing β is low enough, the incumbent enlarges her patent portfolio in order to increase the probability to win the trial; if the cost for implementing β is high enough she sets the minimum size of the patent portfolio to induce collusion.

Summing up, the incumbent might find it optimal to collude with the entrant when the lawsuit cost is low enough and the cost for implementing patent protection is high enough.

The general framework presented in this paper can be extended to any kind of oligopolistic interaction. Here we present a numerical simulation corresponding to the case illustrated in Figure 3, where the positive level of patent protection implemented by the incumbent may be interpreted as a signal of the willingness of a more patient incumbent to induce a less patient entrant to collude. However, any hypothesis on product differentiation (horizontal or vertical), cost asymmetry, geographical distance between markets and so on, just affects the level of the one-shot profits (N, C, D , and M) but does not alter the constraints characterizing the collusive equilibrium.²⁶

We assume that the inverse market demand function is linear and given by $P(q_I, q_E) = a - b(q_I + q_E)$, with $a > 0, b > 0$ where P, q_I and q_E are respectively the market price, the incumbent's and the entrant's output levels, which compete à la Cournot. The cost functions are respectively $C_I(q_I) = cq_I$ and $C_E(q_E) = cq_E$ with $c \geq 0$. In order to simplify calculation, we set $a = b = 1$ and $c = 0$. In this case it is easy to show that one-shot profits of monopoly, Cournot-Nash, collusion and deviation, are respectively $M = 1/4 = 0.25$, $N = 1/9 = 0.11$, $C = 1/8 = 0.125$ and $D = 9/64 = 0.14$. Moreover we set $F = N$, $L = N/10$ and $x(\beta) = \beta^2$ and we assume that the firms' discount factors are respectively equal to $\delta_I = 0.50$ and $\delta_E = 0.20$.

In this case without a system of patent protection collusion is not sustainable: it is easy to check that $\sigma(0) = 0.529421 > \delta_I = 0.50$ and $\sigma(0^+) = 0.24528 > \delta_E = 0.20$. Furthermore, we have $\tilde{\beta}_I = 0.0375 > \tilde{\beta}_E = 0.0075$.

According to our model the incumbent has three strategies: she can foreclose the entry setting $\beta^{fd} = 0.5111$, she can play non collusively setting $\beta^{nc} = 0.1389$ or she can accommodate and collude setting $\beta^{ac} = \tilde{\beta}_E = 0.0075$. It is easy to obtain that $\Pi_I^{ac} = 0.24999 > \Pi_I^{fd} = 0.23876 > \Pi_I^{nc} = 0.17274$: collusion is sustainable and preferred with respect to the alternative strategies.

4 Policy implications and conclusion

Economic literature has pointed out a number of structural elements that may affect firms' ability to collude when implicit price fixing agreement should be self-enforcing: e.g., number of firms, capacity constraints, demand fluctuations, multi-market contacts etc. Antitrust authorities may

²⁶More cases and numerical simulations can be provided on request.

use these elements to identify situations where closer investigations are needed.

In this paper we have obtained some clear results. Building a patent portfolio and threatening patent litigation may be an anticompetitive non-pricing mechanism: a patient incumbent might induce an impatient entrant to collude, avoiding aggressive entries. Furthermore, this strategy maximizes the incumbent's expected profits with respect to other non-cooperative ones, e.g. foreclosing the market. Finally, if the incumbent does not sue the entrant despite owning a patent portfolio, she is trying to collude.

In terms of competition policy and welfare impact evaluation, if it is unquestionable that accommodating entry and colluding is an anti-competitive behavior, we have not to ignore that such a conduct may be caused by an imperfection in the patent awarding system. Farrell and Shapiro (2008) state: "Roughly 15,000 patents a month are issued by the US Patent and Trademark Office (PTO). By law, these are supposed to cover only novel and nonobvious inventions, but an average application gets only about 1520 hours of patent examiner time, and a substantial proportion of the few patents later fully evaluated in court are held invalid." In other words, the PTO tends to delegate decisions about the validity of patents to the courts, creating uncertainty and contributing to make the patent protection system imperfect.

The welfare implications of this imperfection could be different according to the type of firms that we are considering. We can distinguish two cases. The first is the one of an innovative firm: with stochastic patent protection, her monopoly power is not guaranteed and the entry of mimic firms may occur. In this context, a collusive conduct could be the best reply of a firm, that should have become a monopolist, to a non-market imperfection. Moreover, collusion guarantees higher expected R&D returns, stimulating investments. The second case is the one of a non-innovative firm that patents without a clear innovation, undeservedly obtaining market power. In this case, the prospect of collusion does not affect R&D investments and this conduct is unambiguously detrimental to the welfare.

Therefore, in both cases, the solution would be to increase efficiency of the patent granting system reducing the uncertainty associated to patent validity: a perfect patent granting system would guarantee innovative firms, while a market without clear innovations would be open to competition. This solution would increase the costs for the PTO that, given its overload, often prefers to approve most of the patents, delegating their validity to court judgments.

Summing up, our model suggests that patenting may be aimed at

collusion. This result seems in contrast with the traditional economic wisdom that considers patents as an anti-collusive instrument since, in a Schumpeterian perspective (Schumpeter 1942), patents should grant firms temporary monopoly; however, if this statement were true, we should note that in industries characterized by relevant R&D expenditures and huge patent portfolios (for example, the knowledge-base ones) firms rarely collude. On the contrary, coherently with our theoretical results, empirical evidence shows that competitors do enter in markets covered by patents, and collusion often emerges between patenting firms. For example, recent lawsuits for collusion have involved companies in high competitive markets all over the world: in 2005 in the USA, the Samsung pleaded guilty to conspiring with Infineon and Hynix Semiconductor, to fix the price of dynamic random access memory (DRAM); in 2006, the government of France fined 13 perfume brands including L'Oréal, Chanel, LVMH's Sephora and Hutchison Whampoa's Marionnaud for price collusion between 1997 and 2000; in 2008 in the USA, LG Display Co., Chunghwa Picture Tubes and Sharp Corp., agreed to plead guilty for conspiring to fix prices of liquid crystal display panels (LCD); a similar fine was committed in Europe in 2010 to LG, Chimei Innolux, AU Optronics, Chunghwa Picture Tubes Ltd., and HannStar Display Corp.; in 2012, South Korea's antitrust regulator has fined Samsung Electronics and LG Electronics, for conspiring to fix the prices of some appliances (washing machines, flat-panel TVs and laptop computers). Other accusations of collusion have involved some of the Silicon Valley giants (Apple, Adobe, Google, Intel and more) regarding their agreement of not to hire each other's staff, in order to keep wages low.

These markets, from the TV LCD to the perfume one, have a trait in common: there is a huge amount of patents covering and protecting the innovations. Patenting firms collude and, even if sometimes they go to the court, lawsuits often end with out-of-court settlements: usually, firms play with incomplete (or asymmetric) information and the trial may provide the chance to meet each other in "smoke-filled rooms" facilitating collusion. This can explain the reason why a small percentage of trials ends with a verdict.

Starting from the idea of stochastic patent protection, further extensions of our analysis move towards stressing the trade-off between incentives to invest in R&D and incentives to create and enlarge patent portfolios.

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