The effect of imperfect patent protection on licensing

Carlo Capuano* and Iacopo Grassi†

This version: 14 June 2018

Abstract

We extend the literature on licensing, introducing imperfect patent protection. We present a theoretical model where an innovator may license a more efficient technology to an incumbent. Because of imperfect patent protection, the incumbent may imitate the technology with a non-negligible probability to not be convicted. We prove that the introduction of imperfect patent protection reduces the values of both exclusive and sole licenses, making in some cases the latter more profitable for the licensor. As a consequence, on the one hand, the threat of imitation boosts the innovator in the market enlarging the number of firms that operate in the market with the efficient technology, and increasing the allocative and (static) productive efficiency; on the other hand, the same threat reduces the innovator’s expected R&D returns, negatively affecting the ex-ante incentive to innovate, and the dynamic efficiency of the market.

Keywords: patents, entry game, licensing, welfare, efficiency.
JEL Code: L12, L13, D45.

*Department of Economics and Statistics (DISES), University of Naples Federico II - Complesso Universitario di Monte S.Angelo, Via Cinthia, Naples, Italy - tel.+39081675021 - email: carlo.capuano@unina.it
†Department of Political Science, University of Naples Federico II - Via Rodino' 22, Naples, Italy - tel.+390812538229 - email: iagrassi@unina.it
1 Introduction

According to Abhijit (2014), "licensing involves a contractual agreement between a firm (the licensor) who makes a legally protected asset available to others (the licensees) in return for royalties, license fees, and other forms of compensations. The licensed asset is usually a company name, brand name, patent, trade secret, or product formulation". Licensing often involves contract manufacturing, whereby the licensor provides technical specifications to a subcontractor or local manufacturer, who in turn oversees the production. As Anand and Khanna (2000) point out, patent licensing "is one of the most commonly observed inter-firm contractual agreements", and Spulber (2016), citing data from World Bank, notes that "total worldwide royalty payments for IP (patents, trademarks, and copyrights) exceed $289 billion."

The theoretical literature analyzing the relation between licensor and licensees is huge. Katz and Shapiro (1985) show that royalties can be used as a device to elevate prices and the possibility of licensing may decrease the returns to innovation; some literature (Kamien and Tauman, 1986; Gallini and Wright, 1990) analyze the division of the value created by a licensing agreement between the licensor and licensees; more recent literature concentrate on the entry game between licensor and licensees, and the optimal strategies of the first (Sen and Tauman, 2007; Duchene et al., 2015; Chen, 2016; Hattori and Tanaka, 2017).

All previous literature concentrates the analysis on perfect patent protection, ignoring that, in a sense, the protection of a patent is always stochastic, since ex-ante one does not know if a court will recognize its validity. For many years, economists typically looked at patents as an almost perfect way to protect the market. In the standard economics model, a firm creates an invention, covering it with a patent (or a portfolio of patents), which was basically respected by competitors. However, "more recently, scholars and policy-makers have begun to look more closely at the empirical evidence regarding the issuance of patents and patent litigation. Nearly 200,000 patents are issued every year after a very limited examination process. Most issued patents turn out to have little or no commercial significance, which is one reason that only 1.5 percent of patents are ever litigated, and only 0.1 percent of patents are ever litigated to trial. Given these uncertainties, economists have increasingly recognized that a patent does not confer upon its owner the right to exclude but rather a right to try to exclude by asserting the patent in court. When a patent holder asserts its patent against an alleged infringer, the patent holder is rolling the dice. If the patent is found invalid, the property right will have evaporated." (Lemely and Shapiro, 2005, p 75).
In other words, patents do not protect perfectly any invention, and if litigated they have a probability to be invalidated by a court; hence, firms owning patents may lose lawsuits involving their violation (Lemley and Shapiro 2005, Farrell and Shapiro 2008).

Our paper extends the literature on licensing, introducing imperfect patent protection. We present a model where an efficient entrant may license its technology to an incumbent; however, because of imperfect patent protection, the incumbent may imitate the technology of the entrant with a non-negligible probability to not be convicted. In particular, we focus on fixed license fees for using a cost-reducing innovation developed by a potential entrant. The innovator can proposes either an exclusive license that preserves the incumbent’s monopolistic position, or a sole license compatible with the entry of the innovator in the market. In the case the incumbent refuses the license proposal, it can decide to imitate the new technology, with a non-negligible probability to be not convicted in a trial for patents infringement.

We analyze how imperfect patents protection modifies the strategy of the firms, the value of the licenses, and the outcome in the market. In particular, we show that the introduction of an imperfect patent protection reduces the values of both exclusive and sole licenses, making in some cases the latter more profitable for the licensor. An exclusive license ensures that no person or firm other than the named licensee can exploit the relevant intellectual property rights, i.e. use the innovation. Also the licensor is excluded. Conversely, a sole license grants to the licensee the right to use the innovation in a non-exclusive way, since the licensor can exploit the innovation too.

We prove that in the case of non-drastic innovation the innovator always prefers entering the market with a sole license proposal.\footnote{\label{footnote:1}According to Arrow (1962), an innovation is drastic when the monopolistic price computed on the innovative technology is no higher than the marginal cost before the innovation, this means that the innovating firm can be monopolistic, excluding imitation.} Conversely, in the case of drastic innovation, only when the level of patent protection is high enough, the innovator does not enter the market proposing an exclusive license to the incumbent; when the level of patent protection is low the innovator prefers entering the market with a sole license proposal, as in the case of non drastic innovation. Summing up, when the level of patent protection is not so high, the innovator always enters the market offering a sole license to the incumbent, and the value of the license is reduced by the treat of non-convicted imitation. As a consequence, on a one hand, the threat of imitation may enlarge the number of firms that operate in the market with the efficient technol-
ogy, increasing allocative and (static) productive efficiency; on the other hand, the same threat reduces expected R&D returns, negatively affecting the ex-ante incentives to innovate and the dynamic efficiency of the market.

The paper is organized as follows: Section 2 presents the model in general form; Section 3 derives the SPNE in the linear case; Section 4 presents policy implications and conclusions.

2 The model

2.1 The model setting

We consider a market where initially only one firm (the incumbent $I$) operates as monopolist, with a constant marginal cost $c_I$; another firm (the entrant $E$) has a patent on a cost reducing technological innovation, that reduces the cost from $c_I$ to $c_E$. Firm $E$ can license its patent to firm $I$. Firm $I$ can violate the patent, and imitate the innovative technology.

The timing of the game is the following:

- at $t=1$, firm $E$ enters or not the market;
- at $t=2$, firm $E$ offers the license at the fixed-fee $L$ to the incumbent, to use the new technology;
- at $t=3$, firm $I$ accepts or not the contract of licensing;
- at $t=4$, in the case firm $I$ refused the licensing proposal at $t=3$, it imitates or not the innovation;
- at $t=5$, the firms in the market simultaneously and non-cooperatively fix their output levels;
- at $t=6$, in the case of imitation at $t=4$, a court (the nature) convicts the incumbent of patent infringement with probability $g$. In this case, the entrant obtains a fine equal to the incumbent’s profit.

Table (1) summarizes symbols and notations we use in the paper. Figure (1) describes the timing of the game.

In order to obtain the subgame-perfect Nash equilibrium (SPNE), we discuss the equilibria in all the subgames, solving the game by backward induction.
Table 1: Symbols and notations.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e)</td>
<td>firm E enters the market.</td>
</tr>
<tr>
<td>(ne)</td>
<td>firm E does not enter the market.</td>
</tr>
<tr>
<td>(L_e)</td>
<td>license fee, in case of entry.</td>
</tr>
<tr>
<td>(L_{ne})</td>
<td>license fee, in case of non-entry.</td>
</tr>
<tr>
<td>(a)</td>
<td>firm I accepts the license proposal.</td>
</tr>
<tr>
<td>(na)</td>
<td>firm I does not accept the proposal.</td>
</tr>
<tr>
<td>(m)</td>
<td>firm I imitates the innovation.</td>
</tr>
<tr>
<td>(nm)</td>
<td>firm I does not imitate the innovation.</td>
</tr>
<tr>
<td>(g)</td>
<td>the probability to be declared guilty of patent infringement.</td>
</tr>
<tr>
<td>(c_E)</td>
<td>marginal cost of the innovative technology.</td>
</tr>
<tr>
<td>(c_I)</td>
<td>marginal cost of the old technology.</td>
</tr>
<tr>
<td>(M(c_E))</td>
<td>one shot monopoly profit with innovative technology.</td>
</tr>
<tr>
<td>(M(c_I))</td>
<td>one shot monopoly profit with old technology.</td>
</tr>
<tr>
<td>(D(c_E,c_E))</td>
<td>one shot duopoly profit when both firms use innovative technology.</td>
</tr>
<tr>
<td>(D_E(c_E,c_I))</td>
<td>one shot duopoly profit of the Entrant, in asymmetric duopoly.</td>
</tr>
<tr>
<td>(D_I(c_E,c_I))</td>
<td>one shot duopoly profit of the Incumbent, in asymmetric duopoly.</td>
</tr>
</tbody>
</table>

2.2 The non-entry subgame

At \(t=1\), the innovating firm decide to stay out of the market, giving an exclusive license to the incumbent. In this case, firm E’s profit is equal to the license fee. If firm I refuses the license agreement, it can imitate the new technology; a court can convict the imitator, with an exogenous probability \(g\). Under limited liability, we assume the maximum fine, that is equal to the imitator’s profit. Then, firm I’s willingness to pay for the license compares the monopolistic profit using the efficient technology, and the one it obtains refusing the proposal.

Let us describe analytically the outcome of the subgame. Assume firm E proposes a license fee \(L_{ne}\). If firm I accepts the contract, it obtains the monopolistic profit, producing with the innovative technology. The firms’ profits are:

\[
\pi^{ne,a}_I = M(c_E) - L_{ne}; \quad \pi^{ne,a}_E = L_{ne}
\]

If firm I refuses the contract, it can imitate or not the entrant. In the latter case the profits are:

\[
\pi^{ne,na,nnm}_I = M(c_I); \quad \pi^{ne,na,nnm}_E = 0
\]

Imitating:

2 This assumption minimizes the negative impact of an imperfect patent protection on the license value and the innovator’s expected profits. Lower fines increase the strength of our results.
Comparing profits in equations (1), (2), and (3), allows us to state the following proposition:

**Proposition 1** In the non-entry subgame, firm I accepts the license contract, if and only if $L_{ne} \leq gM(c_E)$, and $g \leq g_1 = \frac{M(c_E) - M(c_I)}{M(c_E)}$.

**Proof.** At t=4, firm I imitates, if and only if $\pi_I^{ne,na,m} \geq \pi_I^{ne,na,na}$, i.e. iff $g \leq g_1 = \frac{M(c_E) - M(c_I)}{M(c_E)}$. At t=3, when $g \leq g_1$, firm I accepts the license if and only if $\pi_I^{ne,a} \geq \pi_I^{ne,na,m}$, i.e. iff $M(c_E) - L_{ne} \geq (1 - g)M(c_E) \Rightarrow L_{ne} \leq gM(c_E)$. ■

Proposition 1 implies that, when the level of $g$ is low enough, firm I has an incentive to imitate the new technology. This negatively affects the maximum licensing fee; i.e., $\frac{\partial L_{ne}}{\partial q} \geq 0$. Assuming a take-it-or-leave-it proposal, at t=2, firm E will set the maximum level of $L_{ne}$ compatible
with the firm I’s participation constraint, that is: \( L_{ne} = g M(c_E) \). Thus, in this equilibrium, we have the following profits:

\[
\pi_{ne,a}^I = (1 - g) M(c_E); \quad \pi_{ne,a}^E = g M(c_E)
\]  

(4)

**Corollary 1** In the non-entry subgame, when \( g > g_1 \) firm I accepts the license contract if and only if \( L_{ne} \leq M(c_E) - M(c_I) \).

According to Corollary 1, effective patent protection (i.e., \( g > g_1 \)) ensures the maximum value of the license in this subgame. Firms’ profits are the following:

\[
\pi_{ne,a}^I = M(c_I); \quad \pi_{ne,a}^E = M(c_E) - M(c_I)
\]  

(5)

### 2.3 The entry subgame

When at \( t=1 \) the innovator enters the market, the licensing is not exclusive but sole; thus, in equilibrium we can have either a symmetric duopoly (both firms produce with the marginal cost \( c_E \)), or an asymmetric duopoly (the entrant produces with the marginal cost \( c_E \), the incumbent with the marginal cost \( c_I \)). The symmetric duopoly is efficient, and it occurs either when firm I accepts the license, or it refuses and imitates firm E.4 In the entry subgame it is relevant to distinguish between drastic and non-drastic innovation, because with drastic innovation, the incumbent’s profit in case of asymmetric duopoly is null.

Let us describe analytically the outcome of the subgame. Assume firm E does enter the market, proposing a license fee \( L_e \). If firm I accepts the contract, it obtains the duopolistic profits, producing with a more efficient technology. The profits are:

\[
\pi_{e,a}^I = D(c_E, c_E) - L_e; \quad \pi_{e,a}^E = D(c_E, c_E) + L_e
\]  

(6)

If firm I refuses the contract, it can decide to not imitate the incumbent, continuing to use the older technology, while the competitor uses the innovative one. In this case the profits are:

\[
\pi_{e,na,nm}^I = D(c_I, c_E); \quad \pi_{e,na,nm}^E = D(c_E, c_I)
\]  

(7)

---

3We assume the maximum bargaining power to the innovator. Other bargaining license-fee-fixing mechanisms that reduce license fee, increase the strength of our results.

4Note that firm E obtains at least the symmetric duopolistic profit.
Notice that, with drastic innovation $D(c_I, c_E) = 0$, and $D(c_E, c_I) = M(c_E)$.

In case of imitation, with probability $g$ the incumbent pays a fine equal to its profit. Hence, we have:

$$\pi^{e,na,m}_{I} = (1 - g)D(c_E, c_E); \quad \pi^{e,na,mm}_{E} = (1 + g)D(c_E, c_E) \quad (8)$$

Comparing profits in equations (6), (7), and (8), allows us to state the following proposition:

\textbf{Proposition 2} \textit{In the entry subgame, firm I accepts the license contract, if and only if} $L_e \leq gD(c_E, c_E)$, \textit{and} $g \leq g_2 = \frac{D(c_E, c_E) - D(c_I, c_E)}{D(c_E, c_E)}$.

\textbf{Proof}. At $t=4$, firm I imitates, if and only if $\pi^{e,na,m}_{I} \geq \pi^{e,na,mm}_{I}$, i.e. iff $g \leq g_2 = \frac{D(c_E, c_E) - D(c_I, c_E)}{D(c_E, c_E)}$. At $t=3$, when $g \leq g_2$, firm I accepts the license if and only if $\pi^{e,a}_{I} \geq \pi^{e,na,m}_{I}$, i.e. iff $D(c_E, c_E) - L_e \geq (1 - g)D(c_E, c_E) \Rightarrow L_e \leq gD(c_E, c_E)$. \hfill \blacksquare

Notice that, in case of drastic innovation $g_2 = 1$.

Hence, we have:

$$\pi^{e,a}_{I} = (1 - g)D(c_E, c_E); \quad \pi^{e,a}_{E} = (1 + g)D(c_E, c_E) \quad (9)$$

\textbf{Corollary 2} \textit{In the entry subgame, when} $g > g_2$ \textit{firm I accepts the license contract if and only if} $L_e \leq D(c_E, c_E) - D(c_I, c_E)$.

According to Corollary 2, effective patent protection (i.e., $g > g_2$) ensures the maximum value of the license in this subgame. Firms’ profits are the following:

$$\pi^{e,a}_{I} = D(c_I, c_E); \quad \pi^{e,a}_{E} = 2D(c_E, c_E) - D(c_I, c_E) \quad (10)$$

\section{The SPNE of the game}

In the first part of the paper, we developed the analysis under a general model setting. Hereafter, in order to make the model treatable, we concentrate on the linear case. We assume linear demand function, such that $p = 1 - q_I - q_E$, and, without loss of generality, $c_E = 0$ and $c_I = c$.

Notice that, in our framework, when $c \geq \frac{1}{2}$ the innovation is drastic. It is easy to show that, in case of Cournot competition, we have the following profits:

$$M(c_E) = \frac{1}{4}; \quad M(c_I) = \frac{(1 - c)^2}{4}; \quad D(c_E, c_E) = \frac{1}{9} \quad (11)$$
\[ D(c_E, c_I) = \begin{cases} \frac{(1+c)^2}{9} & \text{if } c \leq \frac{1}{2} \\ \frac{1}{4} & \text{if } c > \frac{1}{2} \end{cases} \]  

(12)

\[ D(c_I, c_E) = \begin{cases} \frac{(1-2c)^2}{9} & \text{if } c \leq \frac{1}{2} \\ 0 & \text{if } c > \frac{1}{2} \end{cases} \]  

(13)

Assuming the profits (11), (12) and (13), the critical levels of probability \( g \) in the two subgames, \( g_1 \) and \( g_2 \), become:

\[ g_1 = c(2-c) \]  

(14)

\[ g_2 = \begin{cases} 4c(1-c) & \text{if } c \leq \frac{1}{2} \\ 1 & \text{if } c > \frac{1}{2} \end{cases} \]  

(15)

Notice that \( g_1 \leq g_2 \); i.e., the incentive to imitate is bigger when the innovative firm enters the market. Then, the following propositions describe the SPNEs. Consider first the case of non-drastic innovation.

**Proposition 3** When innovation is not drastic, firm \( E \) enters the market, proposes the exclusive license, and firm \( I \) accepts for any level of patent protection.

**Proof.** Given that \( g_1 \leq g_2 \), there are three alternative scenarios: (i) \( g \leq g_1 \); (ii) \( g \in (g_1, g_2) \) (i) \( g \geq g_2 \). (i) \( \pi^{ne,a}_E = L_{ne} = gM(c_E) = \frac{g}{4} \); \( \pi^{e,a}_E = L_e + D(c_E, c_E) = (1+g)D(c_E, c_E) = \frac{1+g}{9} \); then firm \( E \) enters the market, and licenses, if and only if \( \pi^{e,a}_E \geq \pi^{ne,a}_E \Rightarrow g \leq \frac{4}{5} \); the latter condition is always satisfied when \( c < \frac{1}{2} \). (ii) \( \pi^{ne,a}_E = L_{ne} = M(c_E) - M(c_I) = \frac{c(2-c)}{4} \); \( \pi^{e,a}_E = \frac{1+g}{9} \); then firm \( E \) enters the market, and licenses, if and only if \( g \geq \frac{9c(1-c)-2}{2} \); the latter condition is always satisfied when \( g \geq g_1 \). (iii) \( \pi^{ne,a}_E = \frac{c(2-c)}{4} \); \( \pi^{e,a}_E = 2D(c_E, c_E) - D(c_E, c_I) = \frac{2}{9} - \frac{(1-2c)^2}{9} \); then firm \( E \) enters the market, and licenses, if and only if \( c \leq \tilde{c} = 0.62641 \), that is always satisfied. 

Proposition 3 shows that the level of patent protection does not affect the entry decision of the innovating firm, but negatively affects the value of the license. Consider now the case of drastic innovation.
Proposition 4 When innovation is drastic, firm E does not enter the market, proposes the exclusive license, and firm I accepts for any \((c, g) \in X\) where 

\[
X = \left\{(c, g) \in \left[\frac{1}{2}, 1\right] \times [0, 1] : g \in \left[\frac{4}{5}, \frac{9c(2-c)-4}{4}\right]\right\}
\]

Proof. If \(c \geq \frac{1}{2}\), then \(g_2 = 1\); thus, there are two alternative scenarios: (i) \(g \leq g_1\); (ii) \(g > g_1\). (i) \(\pi_{E,e}^{n.e.a} = L_{ne} = gM(c_E) = \frac{g}{4}\); \(\pi_{E,a}^{e}\) = \(L_e + D(c_E, c_E) = \frac{1+g}{9}\); then firm E enters the market, and licenses, if and only if \(\pi_{E,a}^{e} \geq \pi_{E,a}^{n.e.a} \Rightarrow g \geq \frac{4}{5}\); i.e., \((c, g) \in X_1 = \{(c, g) \in \left[\frac{1}{2}, 1\right] \times [0, 1] : g \in \left[\frac{4}{5}, c(2-c)\right]\}\). (ii) \(\pi_{E,e}^{n.e.a} = L_{ne} = M(c_E) - M(c_I) = \frac{c(2-c)}{4}\); \(\pi_{E,a}^{e} = \frac{1+g}{9}\); then firm E enters the market, and licenses, if and only if \(g \geq g_3 = \frac{9c(2-c)-4}{4}\); i.e., \((c, g) \in X_2 = \{(c, g) \in \left[\frac{1}{2}, 1\right] \times [0, 1] : g \in \left[c(2-c), \frac{9c(2-c)-4}{4}\right]\}\). From (i) and (ii) firm E does not enter the market for any \((c, g) \in X_1 \cup X_2 = X\).

Proposition 4 shows that, in case of drastic innovation, the level of patent protection not only negatively affects the value of the license, but also the entry decision of the innovating firm. For level of patent high enough the incumbent has not incentive to imitate the innovation; this increases the value of the license, due to the fact the incumbent’s outside option is a null profit. As a consequence, the entrant maximizes its profit licensing the innovation in exclusive, without entering the market.

Figure 2 illustrates the different SPNE of the game. The area \(X = X_1 \cup X_2\) describes the combinations of parameters \(c\) and \(g\) where non-entering and exclusive licensing emerge as part of the equilibrium of the game. We have this result for levels of \(c\) and \(g\) high enough.
4 Policy implications and conclusion

In our model, under non-drastic innovation, exclusive licensing is never profitable in equilibrium, i.e. it never emerges as part of the SPNE. On the contrary, in the case of drastic innovation and levels of patent protection high enough, exclusive licensing can emerge as part of the SPNE. When patent protection is less effective, the incumbent has a positive incentive to imitate the entrant; this reduces the value of the license and boosts the innovator to enter the market and compete with the incumbent.

In terms of welfare, we have twofold implications. On a one hand, the entry of a competitor increases the allocative efficiency in the market; on the other hand, the reduction of the license value negatively affects the R&D return appropriability, decreasing firms incentives to innovate. Assuming that the probability to innovate depends on the expected R&D returns, we have a static versus dynamic trade-off. When the level of patent protection is high enough, the probability of success in innovation is higher and, when innovation occurs, we have a monopoly; conversely low level of patent protection reduces the probability of success in innovation, but, when innovation occurs, we expect an oligopolistic competition.
Alternatively, we could extend our analysis assuming that the R&D returns affect the innovative effort, and the level of cost reduction; in other words, when the patent protection is low, the cost reducing innovation would be lower, in equilibrium leading to a duopolistic market. In this case, the trade-off would be between allocative and productive efficiency.

Our results may be extended to the case of market differentiation. Indeed, highly differentiation increases the market power of the firms, and we expect that this reduces the room for drastic innovation; i.e., in case of separated market cost reduction can not be drastic. In terms of our model, this stimulate the innovative firms to enter the market, with a differentiated good, leading to oligopolistic competition.
References


Chen, C-S (2016), Endogenous market structure and technology licensing, Japan Economic Review.


