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Patent licensing and research exemption

Dusanee Kesavayuth
Department of Economics, University of Essex

Abstract

Within an environment of sequential innovations, real world evidence suggests that the licensing decision of the initial patent can occur either before or after the R&D investment of the follow-on invention. The possibility of licensing after the follow-on invention exists due to the presence of research exemption. This paper examines how the research exemption influences the licensor''s decision to license prior to the discovery of the follow-on invention. Within a three firm setting, the paper reveals that the research exemption does not alter the licensing decision while promoting a stream of future inventions. This provides an argument in support of research exemption as legal scheme.

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1 Introduction

This paper investigates the licensing decision under two different research exemption regimes. We often witness patent infringement especially in biotechnology, biomedical equipment, pharmaceuticals, and computer industries where the innovations are often cumulative. Patent infringement litigation is widely regarded as costly and time-consuming. The infringement is easily avoided by licensing. However, in practice licensing arrangements often are difficult to work out. The prior patentees may not license or choose to license too few firms in order to keep its competitive edge and protect its return. Thus, the assumption of efficient licensing may be difficult to achieve. Evidence of R&D blocking and the difficulty of negotiating a license for an initial patent has been observed since the early 19th century (for example in the case of Wright Brothers' airplane patents). In this case, a strong patent system prevents other firms from utilizing the existing patent due to the possibility of patent infringement and licensing difficulty.

The limited access to available research may retard the resulting flow of innovations especially when innovations are cummulative or sequential. Therefore, it is in the social planner's interest to promote a stream of future innovations. To further this goal, governments grant an exemption to patent infringement when the patent is used purely for research.[1, 2] The research exemption aims to fast track the process of subsequent innovation by allowing more firms to use the existing patent for research purposes, but not commercialisation. There have been legal debates especially over the aspect of the degree to which the research exemption should allow patent use without infringement and how this may affect the dynamics of innovations. There are also debates over the idea that research exemption eliminates the inventor's benefit and diminishes the licensing value which reflects the value of the patent.

Explicit economic modelling of the research exemption appears to be lacking. The paper addresses the question regarding the licensing decision in an environment of sequential innovations. The main question is what are the conditions that the prior patentee would choose to license out its patent to none, to one, or to both lagging firms.[3] The licensing decisions of our focus is licensing at the stage prior to the decision of R&D.[4] We compare the licensing decision when the research exemption does exist to the benchmark case where the exemption of research does not exist. This leads us to analyse how

[1] The research exemption is granted to experimental research on the subject matter for the purpose of i) challenging the validity of the patent, ii) confirming the value of a patent for the purpose of licensing, iii) experimentation for the purpose of improving or finding its use and iv) experimentation for inventing-around.

[2] In the U.S., examples of research exemption are "The Pant Variety Protection Act of 1970" for agricultural industry and the Hatch-Waxman Act of 1984 for the pharmaceutical industry. In Europe, the research exemption is governed by national patent laws and Art. 64 (1) of the European Patent Convention (EPC).

[3] The recent example of an exclusive license is The exclusive license to develop a drug against Leishmaniasis from Max Planck Society to Dafra Pharma R&D in 2008. The recent example of non-exclusive licenses are the case when Amic AB, has been granted a non-exclusive license agreement from Roche Diagnostics for a patent right of NT-proBNP, which is a key cardiac marker for a broad array of cardiovascular conditions in March 2008.

[4] An ex-ante licensing arranging before innovation of the subsequent technology promotes research that would otherwise not take place if the license were arranged ex-post due to a high R&D sunk cost (see Green and Scotchmer, 1995 and Scotchmer, 1996). Also, our model ignores the possibility of invent-around which means the new innovation will not infringe the existing patent and licensing is not required. The possibility of invent-around can make ex-post licensing a preferable strategy to ex-ante (Aoki-Nakaoka, 2006).

research exemption would affect the licensing choice.

The paper is organised as follows. Section 2 presents the model setting. The paper completely characterizes the optimal licensing decision of the prior patentee in section 3, then we conclude the paper in section 4.

2 The Model

2.1 Basic Setting

Assume there are three firms, $i \in \{L, j, h\}$. One of these three firms, firm L, has already invested and discovered the *first technology,* hereafter technology X. For simplicity, assume that the innovation emerges without any delays from a positive investment*,* hence; there is no discount rate*.* Technology X contributes a value of X to the economy. The other two firms, j and h, have potential ideas for a *subsequent technology,* hereafter technology Y*.* The subsequent invention contributes to society an "increment" value Y to the existing value X.[5] The prior technology is the basic knowledge and the follow-on one is the application. Such sequential innovations are frequently observed in biotechnology, biomedical equipment, computer, and pharmaceutical industries.[6]

The firm that firstly discovers each technology will file for a patent. The patent law is strong. Only the firm that patents the technology owns an exclusive right for use of the patent. The model assumes further that technology Y is patentable but it infringes technology X.[7] The license grants the right for use of technology X for the research purpose, but does not grant any right to sublicense.

We explore two legal regimes. The first case is when the research exemption does not exist which is our benchmark. The second case is when the research exemption exists. Then, we compare the licensing decision under these two legal regimes.

[5] The model gives a positive value to the value of the prior patent. However, value X and Y can possibly be normalised to zero and one, respectively, without changing the main findings of the paper. When the prior patent gives a zero market value, it represents a special case of licensing of a research tool or an interim R&D knowledge.

[6] For example, the developement of new drugs consists of several, mostly sequential. First is the discovery phase in which the targeted substance is identified and validated with a medically important function, the lead molecule phase in which the lead molecule that is supposed to interact with the targeted substance is identified and validated. Second is the preclinical phase in which the drug is tested on animals or in vitro. Third is the phase for clinical trails in which the new compound is tested on human subjects and the company file the New Drug Application (NDA) with the Food and Drug Administration (FDA). For some drugs, the FDA requires additional studies (Phase IV) to evaluate long-term effects. In total, the entire development process takes on average 10-12 years.

[7] The patent of technology X is broad with small required inventive step. The breadth and required inventive step are interpreted differently according to the patent law. The breadth is governed by the doctrine of equivalents while the required inventive step is decided based on non-obviousness (see for more detailed discussion in chapter 3 of Scotchmer, 2004).

2.2 Timing and Decision

Figure 1 describes the timing of the game.

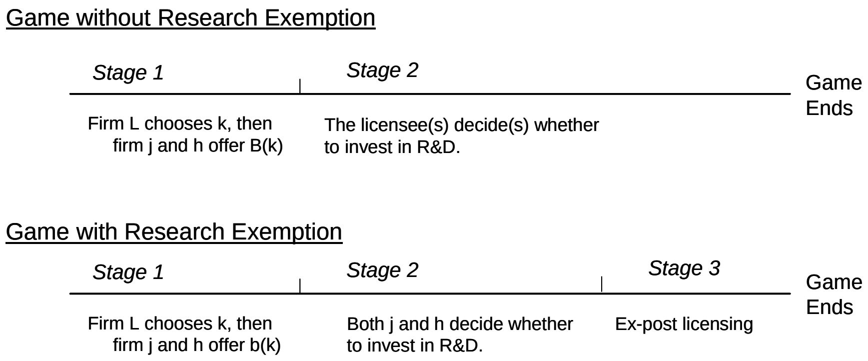

Figure 1: Timing of the Game

First, we analyse the case where the research exemption does not exist (see Figure 1). We call stage 1 the "ex-ante" licensing stage. In this stage, firm L makes a decision regarding the structure of patent licensing for technology X by choosing $k \in \{0, 1, 2\}$, where k is the number of licence(s) that maximize the licensor's profit. 0 implies no licensing, 1 implies exclusive licensing, and 2 implies non-exclusive licensing. Firm j and h bid for the given license(s). If the non-exclusive licenses are issued for both firms, firm L sets a minimum bid to avoid the lowest bid of zero.

The R&D decision is endogenised in stage 2. If a firm decides to undertake R&D for technology Y, it incurs a fixed cost, denoted by R. Firm j and h undertake the R&D investment for technology Y only if their expected payoffs are non-negative. The investment in R&D leads to success with probability $\overline{p}$ if the firm is a licensee. If the research exemption does not exist, the R&D activity using X technology infringes the existing patent. Assume that the cost of patent infringement is high (i.e. full rebate plus litigation cost) so that the non-licensee will face negative returns. Consequently the non-licensee abstains from investing in R&D to avoid infringing technology X patent. The non-licensee's probability of patenting is then zero. The game ends in this stage.

Second, we turn to look at the regime where the research exemption exists. The exemption grants the right to conduct the research related activities [8], but not to commercialize the invention. Under the research exemption regime, the non-licensee can use technology X for research purposes. The non-licensee employs public knowledge disclosed in the patent. In this case, the non-licensee's probability of success is $\underline{p} \in [0, \overline{p})$.[9] This allows the game to proceed to one additional stage where the non-licensee who discovers and patents technology Y negotiates with firm L for technology X license after the

[8] In practice, the research exemption varies across jurisdictions. In this model, we allow the exemptions for all kinds of research and development activities.

[9] This is a rather strong assumption but it could be justified by the fact that the language used in the patent document is rather complicated and it does not provide "all" knowledge of the patented technology, but only at minimum requirement to demonstrate the novelty of the invention. The patentee possesses a stock of unpatented knowledge and/or extra information not listed in the patent. This privately owned knowledge is "know-how." When licensing, the patentee transfers technology "know-how" to the licensee(s) above and beyond the knowledge in the patent disclosure. Hence, it is reasonable to assume $\overline{p} > \underline{p}$.

discovery so that technology Y can be commercialized. We call stage 3 the "ex-post" licensing stage (see Figure 1). The game ends in stage 3.

Our solution concept is subgame-perfect Nash equilibrium. The licensing decisions under two legal regimes are fully categorized, starting with the benchmark case where research exemption does not exist, followed by the research exemption regime.

3 Equilibrium Licensing

3.1 Licensing Without Research Exemption

Due to the existence of patent infringement and absence of the research exemption, the licensing needs to be arranged prior to the R&D decision stage. The game has only two stages (1 and 2).

3.1.1 The R&D Decision:

Starting with the R&D stage, only the ex-ante licensee will invest in R&D. The non-licensee's probability of patenting technology Y is zero. The ex-ante licensee compares the cost of doing R&D, R, with the expected gains of innovation. The licensee undertakes R&D with the following probability of patenting technology Y:

$$\begin{aligned}\Phi_j(1) &= \overline{p} \\ \Phi_j(2) &= \overline{p}(1-\frac{1}{2}\overline{p})\end{aligned}$$

Even though the R&D paths are diversified, all paths aim at obtaining the same invention. If there are many firms conducting R&D, there will be only one firm that obtains the patent for the invention. In case that many firms discover technology Y at the same time, the patent will be assigned to one of those inventors randomly with equal probability.

The payoffs for the licensee are

$$\begin{aligned}\Pi_j(1) &= \overline{p}Y - R \\ \Pi_j(2) &= \overline{p}(1-\frac{1}{2}\overline{p})Y - R\end{aligned}$$

The licensee(s) only undertake(s) R&D investment if the expected payoff is non-negative. Lemma 1 summarizes the R&D decision.

Lemma 1 *(i) if $R \geqslant \overline{p}Y$, no firm invests in R&D for technology Y*
(ii) if $\overline{p}Y > R \geqslant \overline{p}(1-\frac{1}{2}\overline{p})Y$, then one licensee invests in R&D for technology Y, and
(ii) if $R < \overline{p}(1-\frac{1}{2}\overline{p})Y$, then two licensees invest in R&D for technology Y.

Proof. The proof is straightforward, so it is omitted. ■

As Lemma 1 indicates, the ex-ante licensee invests in R&D if the cost of innovation is sufficiently low. It also reveals that the R&D incentive is decreasing in the number of firms that carry out R&D. This reflects that an increase in the number of players competing for the same R&D reduces the firm's probability of winning. Consequently, each firm requires a cheaper R&D investment to break-even.

3.1.2 The Ex-ante Licensing:

Firm L chooses the number of licenses (k) to maximize its profit. Then, firm j and h offer their bids given the number of licenses. The licensee's payoff equals $\Pi_j(k)$. Therefore, the bid $B(k)$ for k given licenses, is

$$B(k) = \Pi_j(k) - \Pi_h(k) = \Phi_j(k)Y - R.$$

Notice that the potential licensee incorporates the cost of innovation into the bid. In our model, the auction occurs before the R&D stage and the non-licensee cannot invest in R&D. These imply that the non-licensee's payoff, $\Pi_h(k)$, is zero. This is a threat point when calculating the bid. The licensee may hold-up its investment if it must pay a high fee for the license such that it cannot cover the R&D cost. The licensor who would like to obtain an extra reward from the innovation can ensure that the subsequent innovation goes forward by accepting a lower fee. Firm L's payoffs for given k are

$$\begin{aligned}\Pi_L(0) &= X\\ \Pi_L(1) &= X + B(1)\\ \Pi_L(2) &= X + 2\ B(2)\end{aligned}$$

The licensing equilibria are categorized according to the value of R&D investment obtained in Lemma 1.

Proposition 1 *If the exemption of research does not exist, in equilibrium firm L*
(i) does not license to any firms if $R \geqslant \overline{p}Y$.
(ii) licenses exclusively if $\overline{p}(1-\overline{p})Y \leqslant R < \overline{p}Y$.
(iii) licenses non-exclusively to both firms if $R < \overline{p}(1-\overline{p})Y$.

Proof. See Appendix II. ■

The intuition behind Proposition 1 hinges on two effects. The first effect captures the R&D complementarity effect, which shows the additional probability of discovering the new invention when there is one additional licence. This effect is positive in our model. For example, the R&D complementarity effect is $\overline{p}Y$ for the first license and $\overline{p}(1-\overline{p})Y$ for the second license.[10] The second effect reflects the duplicative R&D cost, which is transferred from the licensee via the bid. Since the bid includes the cost of R&D investment, the licensor fully bears the additional cost after granting the additional license. The duplicative R&D cost effect is $-R$ for each additional license. This effect is a negative force in our model.

Despite the positive R&D complementarity effect, the cost of R&D could be too high. Firm L has to trade off the additional R&D cost that it bears against the incremental probability of discovering for the additional license. If the cost of R&D is relatively high ($R \geqslant \overline{p}Y$), offering any licenses would be too costly for the licensor. Within this range, the duplicative R&D cost effect is dominant. Hence, firm L does not offer any licenses. If the cost of R&D is intermediate, $\overline{p}(1-\overline{p})Y \leqslant R < \overline{p}Y$, the cost of R&D is sufficient low for only one R&D lab to operate without loss. Hence, it is profitable for firm L to issue an exclusive license. If the cost of R&D is sufficiently low, $R < \overline{p}(1-\overline{p})Y$, the positive R&D

[10]The R&D complementarity effects are $[\Phi_j(1) - \Phi_j(0)]Y$ and $[\Phi_j(2) - \Phi_j(1)]Y$, for exclusive and non-exclusive licenses, respectively.

complementarity effect is dominant. Hence, firm L is better off licensing non-exclusively to both firm j and h.

The duplicative R&D cost effect in our model influences our result along the same line with the result in Proposition 1 of Green and Scotchmer (1995). Green and Schotchmer find that the first patentee shares half of the cost of the new innovation with subsequent patentee using an ex-ante licensing arrangement. The R&D cost sharing is beneficial when it is not profitable for the licensee to bear it alone. The licensor helps its licensee to innovate by reducing the fee collected for its patent, in order to share the cost of R&D for technology Y. With respect to this point, our model delivers a stronger result that the bidders transfer all the cost to the licensor via their bids. The licensor bears all the cost for new innovation. The difference in the result is due to the different ex-ante licensing arrangements. Green and Scotchmer (1995) models ex-ante licensing using fixed fee negotiation, but our paper models an ex-ante licensing using auction (aiming to avoid complication of multi-agents bargaining). The subsequent inventor retains some positive profit in Green and Scotchmer (1995), while in our paper the licensee cannot retain profit in the benchmark model. The R&D complementary effect is an additional feature. The R&D complementarity effect is not a new effect but has been firstly discussed in Bessen and Maskin (forthcoming). The contribution of our paper is an attempt to combine these specific two effects in one place to analyse the licensing decision and research exemption.

Proposition 1 can be rewritten in term of reward or market size of the subsequent inventions, Y. Firm L licenses to more firms when new invention market is sufficiently large. Intuitively, the larger the market size or the reward of the innovation, the higher R&D cost that firm L is willing to pay.

3.2 Licensing With Research Exemption

In this section, we assume that the patent laws allow the research exemption. The effect of the exemption in the game is to allow the possibility of negotiation for a license after the research stage. The ex-ante non-licensee(s) can conduct R&D without infringing the existing patent. Under this regime, firm L has an incentive to provide the ex-post license because both parties are better off if the inventor can commercialize technology Y. The ex-ante non-licensee realizes that there is the possibility of obtaining an ex-post license. Therefore, it will no longer abstain from investing in the new R&D. As the result, the ex-ante licensee also adjusts the bid for the ex-ante license.

The research activity does not infringe firm L's existing patent. Thus, firm j and h carry out R&D with each firm's probability of patenting technology Y given by

$$\begin{aligned}
\Phi_j(k) &= p_j(1-p_h) + \frac{1}{2}p_j p_h \\
\Phi_h(k) &= p_h(1-p_j) + \frac{1}{2}p_j p_h
\end{aligned}$$

The non-licensee's probability of success is positive but lower than the licensee's, $\underline{p} \in (0, \overline{p})$. Appendix I shows $\Phi_i(k)$ for all $k \in \{0, 1, 2\}$. It is important to note that the non-licensee can discover and obtain the patent even its probability of discovering is lower than the licensee's. This scenario is observed in real markets where new inventions are invented by firms that are not the market leaders or the owners of the existing patents.

3.2.1 The Ex-post Licensing:

An ex-post licensing is defined as the licensing of blocking patent X after discovery of technology Y. If the non-licensee discovers and patents technology Y, then firm L and the non-licensee (firm h) engage in ex-post licensing. Let assume that firm h pays a fixed fee, $f(k)$, which is the outcome of bilateral bargaining between the two parties over the rent. The licensor expects this fee only when the non-licensee wins the patent for technology Y which arises with the probability $\Phi_h(k)$. Firm L captures a share $0 < \beta \leqslant 1$ of the gain on technology Y.[11] Using Nash Bargaining, the two parties optimally agree to split half of this gain at the equilibrium, i.e. $\beta = \frac{1}{2}$.[12]. In this case, the cost of innovation is a sunk cost because the two parties negotiate after the R&D cost has been spent. Therefore, it is excluded from the bargaining. The negotiation results is an expected value of the half split of value of technology Y, which is

$$f(k) = \Phi_h(k)\frac{1}{2}Y$$

We obtain the fixed licensing fee as $f(0) = \left[\underline{p} - \frac{1}{2}\underline{p}^2\right]\frac{1}{2}Y$ and $f(1) = \left[\underline{p} - \frac{1}{2}\underline{p}\overline{p}\right]\frac{1}{2}Y$. The ex-ante non-licensee's payoffs are

$$\begin{aligned} \pi_h(0) &= \left[\underline{p} - \frac{1}{2}\underline{p}^2\right]\frac{1}{2}Y - R \\ \pi_h(1) &= \left[\underline{p} - \frac{1}{2}\underline{p}\overline{p}\right]\frac{1}{2}Y - R \end{aligned}$$

3.2.2 The R&D Decision:

The ex-ante licensee and non licensee make their R&D decisions facing different expected payoffs. The next lemma summarizes the R&D decision of the players.

Lemma 2 *(i) if $R \geq \overline{p}Y$, then neither the licensees nor the non-licensees invests in R&D for technology Y.*

(ii) if $\overline{p}(1 - \frac{1}{2}\underline{p})Y \leq R < \overline{p}Y$, then only one ex-ante licensee invests in R&D.

(iii) if $\frac{1}{2}\underline{p}(1 - \frac{1}{2}\underline{p})Y \leq R < \overline{p}(1 - \frac{1}{2}\underline{p})Y$, then both of the ex-ante licensees invest in R&D.

(iv) if $\frac{1}{2}\underline{p}(1 - \frac{1}{2}\overline{p})Y \leq R < \frac{1}{2}\underline{p}(1 - \frac{1}{2}\underline{p})Y$, then both of the ex-ante licensees invest. However, the non-licensee invests if and only if there is no ex-ante license.

(v) if $R < \frac{1}{2}\underline{p}(1 - \frac{1}{2}\overline{p})Y$, then either the licensees, or the non-licensees invest in R&D.

Proof. The proof is straightforward, so it is omitted. ■

The similar two effects govern R&D decision as in section 3.1. Lemma 2 reveals in additional that the ex-ante non-licensee's incentives to innovate is lower than the licensee's. This arises due to the fact that the non-licensee's probability of patenting is lower than the licensee's and the non-licensee has to pay a fixed fee for the ex-post license. Both reduce the ex-ante non-licensee's expected payoff in stage 2.

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[11] We can interpret the bargaining share as reflecting a patent policy choice. The higher the value of β, the more "pro-patent" the policy: more rights accrue to the firms that own the existing patent. If $\beta = 1$, this implies a "take it or leave it" fixed fee when the initial technology patentee gets full bargaining power.

[12] Hence, we are neutral here about how "pro-patent" policy is.

3.2.3 The Ex-ante Licensing:

For given number of licenses (k), firm j and h offer their bids taking into account the possibility that the non-licensee can obtain license ex-post. If the R&D cost is rather high, the ex-ante non-licensee does not invest in R&D. Each bidder then offers its bid as if it is the only firm investing in the subsequent technology. In this case, the licensor's revenue comes from the ex-ante licensing auction only. On the contrary, if the ex-ante non-licensee invests in R&D, $\pi_h(k)$ is not zero. The licensor can expect also additional revenue from the ex-post licensing fixed fee. The bidder recalculates the bid using the following equation.

$$b(k) = \pi_j(k) - \pi_h(k) = [\Phi_j(k) - \Phi_h(k)]\, Y$$

The bidders exclude the cost of R&D (R) from their bids. The research exemption alters the threat point by converting the R&D cost to a sunk cost. Therefore, the duplicative R&D cost effect disappears.

Firm L's payoff for given k are

$$\begin{aligned} \pi_L(0) &= X + 2\, f(0) \\ \pi_L(1) &= X + b(1) + f(1) \\ \pi_L(2) &= X + 2\, b(2) \end{aligned}$$

We proceed to identify the licensing equilibria. The licensing equilibria are categorized according to the value range of the R&D investment obtained in Lemma 2. The next proposition reports our finding.

Proposition 2 *If the exemption of research does exist, in equilibrium firm L*
(i) does not license to any firms if $R \geqslant \overline{p}Y$
(ii) licenses exclusively if $\overline{p}(1-\overline{p})Y \leqslant R < \overline{p}Y$
(iii) licenses non-exclusively to both firms if $R < \overline{p}(1-\overline{p})Y$

Proof. See *Appendix III* ■

We shall see that firm L's equilibrium licensing decision under research exemption regime in proposition 2 is similar to proposition 1. The licensing decision remains unchanged regardless of the presence of research exemption. Even though the research exemption helps the licensor to eliminate the negative effect of the R&D duplicative cost and results in a purely positive effect from R&D complementarity, this arises only when the cost of R&D is sufficiently low (such that the ex-ante non-licensee undertakes R&D). The low cost of R&D implies that the R&D complementarity effect is already a dominant force and the negative effect from duplicative R&D cost is already weak. Therefore, the research exemption neither promotes, nor discourages licensing in our model.

Figure 2 presents firm L's licensing decision.

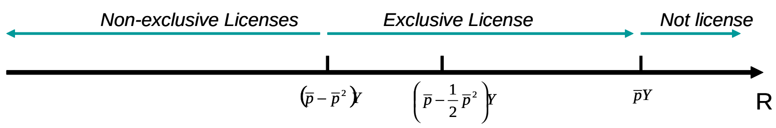

Figure 2: Firm L's Licensing Decisions

4 Conclusion

This paper examines the licensing decision of a patentee who owns a patent of an initial technology or a research tool in a sequential innovation environment. We investigate two different legal regimes, with and without research exemption. The findings in the underlying framework show that the licensing decision depends on the interplay between two effects: the positive R&D complementarity effect and the negative duplicative R&D cost effect. The patentee does not license its patent if the cost of the subsequent invention is relatively high. This implies that the duplicative R&D cost effect dominates the positive R&D complementarity effect. An exclusive licensing may arise in equilibrium when the cost of R&D is at an intermediate level. A non-exclusive licensing may arise when the cost of R&D is sufficiently low. We can also interpret this result in terms of the market size or net reward to the new invention. Our finding provides an explanation to the observed exclusive licence for the patent leading to a small value invention. For example, the medicine for very rare illness or illness in the developing countries such as Leishmaniasis. On the contrary, we observe non-exclusive licences in the market where the reward of discovery is larger. For example, the treatment for more common diseases or illness in the developed countries such as ones related to cardiovascular problems.

The paper analyses the licensing decision under the "research exemption" regime. We find that the presence of the research exemption does not change the initial patentee's licensing decision. Even though the research exemption is effective in eliminating the duplicative R&D cost effect, this arises only when the R&D cost is sufficiently low. This implies that the magnitude of the duplicative R&D cost effect is already dominated by the R&D complementarity effect. Hence, the existence of research exemption neither promotes, nor obstructs licensing.

Appendix I

Table A.I: Probability of Patenting Technology Y

i=j	$\Phi_j(k)$
$k=0$	$\Phi_j(0) = \underline{p}(1-\underline{p}) + \frac{1}{2}\underline{p}^2$
$k=1$	$\Phi_j(1) = \overline{p}(1-\underline{p}) + \frac{1}{2}\underline{p}\overline{p}$
$k=2$	$\Phi_j(2) = \overline{p}(1-\overline{p}) + \frac{1}{2}\overline{p}^2$
i=h	$\Phi_h(k)$
$k=0$	$\Phi_h(0) = \underline{p}(1-\underline{p}) + \frac{1}{2}\underline{p}^2$
$k=1$	$\Phi_h(1) = \underline{p}(1-\overline{p}) + \frac{1}{2}\underline{p}\overline{p}$
$k=2$	$n.a.$

Appendix II

(Proof of Proposition 1)

To prove proposition 1, we need three lemmas (A2.1-A2.3).

Lemma A2.1: Given that $R \geq \overline{p}Y$, firm L choose not to license its patent.

Proof. In this region, no one invests in R&D for technology Y due to an high cost of R&D regardless the number of licenses. Hence, $\Pi_L(0) = \Pi_L(1) = \Pi_L(2) = X$. Since licensing does not contribute to any additional profit, firm L does not license to any other firms. ■

Lemma A2.2: Given that $\overline{p}(1-\frac{1}{2}\overline{p})Y \leq R < \overline{p}Y$, firm L licenses exclusively.

Proof. If $\overline{p}Y > R \geqslant \overline{p}(1-\frac{1}{2}\overline{p})Y$, then it is profitable for only one licensee to invest in R&D for technology Y. If the firm is the non-licensee, it does not invest in technology Y, therefore it obtains zero profit. Then, the optimal bid for the exclusive license equals $B(1) = \overline{p}Y - R$. If there are two licenses, it is not profitable for both firm j and h to invest in R&D. Therefore, they offer $B(2) = 0$ for any non-exclusive licenses.

Firm L's objective is $\Pi_L(k) = X + k\ B(k)$. After substituting the relevant values of the bids, firm L's payoffs are $\Pi_L(0) = X$, $\Pi_L(1) = X + \overline{p}Y - R$, and $\Pi_L(2) = X$. We rank firm L profit to identify the profit maximizing licensing strategy. We obtain $\Pi_L(1) > \Pi_L(0) = \Pi_L(2)$, for $\overline{p}Y > R \geqslant \overline{p}(1-\frac{1}{2}\overline{p})Y$. ■

Lemma A2.3: Given that $R < \overline{p}(1-\frac{1}{2}\overline{p})Y$, (i) firm L licenses exclusively if $\overline{p}[1-\overline{p}]Y \leq R < \overline{p}(1-\frac{1}{2}\overline{p})Y$, and (ii) firm L licenses non-exclusively if $R < \overline{p}[1-\overline{p}]\ Y$.

Proof. If $R < \overline{p}(1-\frac{1}{2}\overline{p})Y$, then, it is profitable for both licensees to invest in R&D for technology Y. If firm L licenses exclusively, only one firm can undertake R&D, hence the firms bid $B(1) = \overline{p}Y - R$. If firm L licenses non-exclusively, minimum bids are optimally set at $B(2) = \Pi_j(2) - \Pi_h(1)$. Since the non licensee cannot undertake R&D, $\Pi_h(1) = 0$. The minimum bid is given by $B(2) = \overline{p}(1-\frac{1}{2}\overline{p})Y - R$.

Firm L's total payoffs are; $\Pi_L(0) = X$, $\Pi_L(1) = X + \overline{p}Y - R$, and $\Pi_L(2) = X + 2\left[\overline{p}(1-\frac{1}{2}\overline{p})Y - R\right]$ .We rank firm L profit to identify the profit maximizing licensing strategy. We obtain (i) $\Pi_L(1) - \Pi_L(0) > 0$, (ii) $\Pi_L(2) - \Pi_L(0) > 0$, and (iii) $\Pi_L(2) - \Pi_L(1) = \overline{p}Y[1-\overline{p}] - R$.

From (iii) we know that $\Pi_L(2) > \Pi_L(1)$ if and only if $R < \overline{p}[1-\overline{p}]\ Y$. In addition, $\forall\ p \in (0,1)$, $\overline{p}[1-\overline{p}] < \overline{p}(1-\frac{1}{2}\overline{p})$. Therefore, $\Pi_L(1) > \Pi_L(2) > \Pi_L(0)$ if $\overline{p}[1-\overline{p}]Y \leq R < \overline{p}(1-\frac{1}{2}\overline{p})Y$, and $\Pi_L(2) > \Pi_L(1) > \Pi_L(0)$ if $R < \overline{p}[1-\overline{p}]\ Y$. ■

From Lemma A2.1 to A2.3, firm L's licensing equilibria are given by

$$k^* = \left\{ \begin{array}{c} 0, \text{ if } R \geqslant \overline{p}Y \\ 1, \text{ if } \overline{p}(1-\overline{p})Y \leqslant R < \overline{p}Y \\ 2, \text{ if } R < \overline{p}(1-\overline{p})Y \end{array} \right\}. \textbf{ QED}$$

Appendix III

(Proof of Proposition 2)

To prove Proposition 2, we need three lemmas.

Lemma A3.1: Given that $\frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y \leqslant R$, firm L's licensing equilibria follows proposition1.

Proof. If $\frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y \leqslant R$, the ex-ante non-licensee(s) does not invest in R&D. Hence, there is no ex-post licensing. Firm L's profits for a given number of licenses are the same regardless of the presence of research exemption. *Therefore, Lemma A2.1, A2.2 and A2.3 holds.* ■

Lemma A3.2: Given that $\frac{1}{2}\underline{p}(1-\frac{1}{2}\overline{p})Y \leqslant R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y$), firm L licenses non-exclusively.

Proof. If $\frac{1}{2}\underline{p}(1-\frac{1}{2}\overline{p})Y \leqslant R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y$), then there are three possibilities for $k \in (0,1,2\}$. If firm L does not licenses ($k=0$), both firm j and h are non-licensees and do invest in R&D. Hence, firm L expects the fixed licensing fee equals $f(0) = \frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y$, but no revenue from an auction. If firm L licenses exclusively ($k=1$), only the ex-ante licensee innovates. The expected ex-post fixed fee $f(1)=0$,while each bidder offers $b(1) = \overline{p}Y - R$ for the exclusive license. If firm L licenses non-exclusively ($k=2$), both licensees innovate and pay the minimum bid of $b(2) = \overline{p}(1-\frac{1}{2}\overline{p})Y - R$.

Therefore, $\pi_L(k)$ are $\pi_L(0) = X + \underline{p}\left[1-\frac{1}{2}\underline{p}\right]Y$, $\pi_L(1) = X + \overline{p}Y - R$. and $\pi_L(2) = X + 2\left[\overline{p}(1-\frac{1}{2}\overline{p})Y - R\right]$. We obtain (i) $\Delta_{12} = \pi_L(1) - \pi_L(2) = R - \overline{p}Y(1-\overline{p})$ which is increasing in R. If R is at its upper-bound, we obtain $\Delta_{12} < 0$ for all $\underline{p} < \overline{p}$, which implies $\pi_L(1) < \pi_L(2)$ for all $R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y$). (ii) $\Delta_{02} = \pi_L(0) - \pi_L(2) = (\underline{p} - \frac{1}{2}\underline{p}^2 - 2\overline{p} - \overline{p}^2)Y + 2R$ which is increasing in R. If R is at it upper-bound, we obtain $\Delta_{02} < 0$ for all $\underline{p} < \overline{p}$. Hence, $\Delta_{02} < 0$ which implies $\pi_L(0) < \pi_L(2)$ for all $R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\underline{p})Y$). From (i) and (ii), $\pi_L(2)$ is maximum. ■

Lemma A3.3: Given that $R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\overline{p})Y$, firm L licenses non-exclusively.

Proof. If $R < \frac{1}{2}\underline{p}(1-\frac{1}{2}\overline{p})Y$, all firms can conduct R&D. If firm L does not license, firm j and h undertake R&D. Each firm pays $f(0) = \frac{1}{2}\underline{p}\left[1-\frac{1}{2}\underline{p}\right]Y$. There are not any revenues from auction. If firm L licenses exclusively ($k=1$), then each bidder offers $b(1) = \Phi_j(1)Y - R - \Phi_h(1)\frac{1}{2}Y - R \Longrightarrow (\overline{p} - \frac{1}{2}\underline{p} - \frac{1}{4}\overline{p}\underline{p})Y$ taking into account that the non-licensee also invests in R&D. If firm L licenses non-exclusively ($k=2$), the minimum bid for non-exclusive license is $b(2) = \Phi_j(2)Y - R - \Phi_h(1)\frac{1}{2}Y - R = (\overline{p} - \frac{1}{2}\overline{p}^2 - \frac{1}{2}\underline{p} + \frac{1}{4}\overline{p}\underline{p})Y$.

Therefore $\pi_L(k)$ are $\pi_L(0) = X + \underline{p}\left[1-\frac{1}{2}\underline{p}\right]Y$, $\pi_L(1) = X + (\overline{p} - \frac{1}{2}\overline{p}\underline{p})Y$, and $\pi_L(2) = X + 2\left[(\overline{p} - \frac{1}{2}\overline{p}^2 - \frac{1}{2}\underline{p} + \frac{1}{4}\overline{p}\underline{p})Y\right]$. We obtain (i) $\Delta_{21} = \pi_L(2) - \pi_L(1) = (\overline{p} - \underline{p})(1-\overline{p})Y$. It is obvious that $\Delta_{21} > 0$ which implies $\pi_L(2) > \pi_L(1)$ for all $\underline{p} < \overline{p}$. (ii) $\Delta_{20} = \pi_L(2) - \pi_L(0)$ $= (2\overline{p} - \overline{p}^2 + \frac{1}{2}\overline{p}\underline{p} - 2\underline{p} + \frac{1}{2}\underline{p}^2)Y$. Assume further that $\underline{p} = \delta\overline{p}$ where $\delta \in (0,1)$. We can rewrite $\Delta_{20} = \frac{1}{2}\overline{p}(\delta-1)((2+\delta)\overline{p} - 4) > 0$ which implies $\pi_L(2) > \pi_L(0)$, given that $\overline{p}, \delta \in (0,1)$. From (i) and (ii), $\pi_L(2)$ is maximum. ■

Due to *Lemma A3.1 to Lemma A3.3*, the licensing decision is

$$k^{RE} = \left\{ \begin{array}{c} 0, \text{ if } R \geqslant \overline{p}Y \\ 1, \text{ if } \overline{p}(1-\overline{p})Y \leqslant R < \overline{p}Y \\ 2, \text{ if } R < \overline{p}(1-\overline{p})Y \end{array} \right\}. \textbf{ QED}$$

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