EXCLUSIVE OR OPEN?
AN ECONOMIC ANALYSIS
OF UNIVERSITY INTELLECTUAL
PROPERTY PATENTING
AND LICENSING STRATEGIES

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With the aim of making public research organizations (PROs) to contribute more to economic development, in the last three decades universities all around the world have been encouraged to valorize their research results by national and regional governments. University basic research is valorized once it attracts the industry attention and is developed into new technologies for commercial and industrial use (Ho et al., 2013). There exist many channels through which a university invention can be transferred to the industry, some formal and other more informal (Mowery et al., 2001; Mowery, Shane, 2002; Siegel et al., 2003; Grimpe, Fier, 2010; Grimpe, Hussinger, 2013). The main focus of this paper is on technology transfer through publication versus formal licensing contracts. In this latter case, and

as opposed to the historical tradition of making university research publicly available to firms via scientific publications, universities protect their intellectual property (mostly via patents but also copyrights for software) and then transfer it to the industry through the use of contractual mechanisms such as licensing.

The attention paid by PROs to this formal model of technology transfer is perfectly illustrated by the worldwide boom of university patenting and licensing (often exclusive licenses) observed since the 1980s (Mowery et al., 2001; Cesaroni, Piccaluga, 2002; Mazzoleni, Sampat, 2002; Mowery, Ziedonis, 2002; Sampat, 2006; Azagra-Caro et al., 2006; Geuna, Nesta, 2006; Carayol, 2007; Lissoni et al., 2008). This evolution in research valorization strategy of universities went hand in hand with the creation or reinforcement of structures dedicated to technology transfer (often called technology transfer offices (TTO)) and the evolution of national legal frameworks towards higher financial returns for university research.

Given this situation, it is important to understand the determinants of PROs’ publishing versus patenting and licensing strategies, i.e. how the context affects the choice of a strategy, the performance of the transfer, the outcome for the different stakeholders and the surplus for society. Indeed, choosing the most appropriate strategy is not an easy task for PROs. It depends heavily on different parameters. For instance, Pénin (2010a) proposes that the nature of the invention, the technological regime and the competition regime are important determinants of the licensing strategy (see Table 1). More broadly, it also depends on the type of PROs and their

| Table 1 – The Determinants of Socially Optimal University Licensing Strategy (based on Pénin, 2010a) |
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| **Nature of Invention**                                       | **Exclusive licensing strategy if**                           | **Non-exclusive licensing or more open strategies if**        |
| Specificity                                                   | Specific                                                      | Generic                                                      |
| Distance to the market                                       | Embryonic                                                    | Mature                                                       |
| Technological Regime                                          |                                                               |                                                             |
| Appropriability                                               | Weak                                                          | Forte                                                        |
| Complexity                                                   | Simple (discrete)                                            | Complex                                                      |
| Speed of technical progress                                   | Slow                                                          | Rapid                                                        |
| Competition Regime                                            |                                                               |                                                             |
| Size of market                                               | Small                                                         | Large                                                        |
| Intensity of competition                                     | High                                                          | Low                                                          |
| Type of the Licensee Firm                                     |                                                               |                                                             |
| Firm size                                                    | Small                                                         | Large                                                        |
| Firm life stage                                              | Start-up                                                      | Mature                                                       |

**Note:** This table must be understood *ceteris paribus*. The characteristic attributed for each variable is determined in order to maximize social welfare, not necessarily universities’ licensing revenues.
objectives. PROs are not the same in all countries. They evolve in a particular socio-economic and institutional environment which obviously affects their strategy and, in particular their objective. In some cases, PROs have set-up independent TTOs whose objective is largely profit driven. In other cases the transfer follows different, often non-monetary logics. Those things should be kept in mind when reading this paper. In particular, they oblige us to be very humble and careful when analysing the implications of our research.

In this work we consider the case of a PRO whose objective is to maximize its profits. We seek to understand the strategy that will be chosen and the performance of the transfer according to the nature of the invention and, in particular, to two important variables: whether or not the invention is embryonic or mature (Jensen, Thursby, 2001); and whether or not it is generic (general purpose technology) or specific. To do so we consider a sequential model in which a university wants to transfer an invention to the industry and must choose its valorization strategy. In the first stage the university must decide whether to publish or to patent its invention. If the invention is patented, in the second step the university must decide about its licensing strategy (exclusive license, non-exclusive license, exclusive license per field of use). Then in the third step firms must decide whether or not to adopt the invention. We then investigate in which context the university should grant exclusive licenses and in which ones it should grant non-exclusive licenses or publish its research results.

One of the main results of this work is that university licensing strategies must be tailored to the context. In some cases exclusive licensing maximize social welfare (in the case of an embryonic invention for instance). In other cases more open strategies, based on publication, dominate (when the invention is mature and generic for instance). A second important result is that the university, since it seeks to maximize its profits, may not always automatically adopt the licensing strategy that maximizes social surplus. We believe that our work has therefore important policy implications as to the way TTOs should manage the transfer of technologies coming out of public research.

In section 2, we discuss the welfare implications of licensing strategies with varying degrees of openness by referring to three examples of exclusive and non-exclusive licensing. Section 3 presents the model to analyse the effect of the nature of the invention on technology transfer performance. Section 4 concludes by discussing the implications of our findings as well as providing limitations of this paper and recommendations for future research.
Different Degrees of Exclusivity

World Intellectual Property Organization (WIPO) defines licensing agreement as “[A] partnership between an intellectual property rights owner (licensor) and another party (licensee) who is authorized to use such rights in exchange for an agreed payment (fee or royalty)” (Licensing of Intellectual Property Rights, 2014). Thus, in our context, a license can be considered as a contract between the owner of IPR (university) and licensee (firm), under which the firm is given a right to use, reproduce and commercialize the invention developed by the university under specified conditions in the contract.

Among the many things that must be specified in licensing contracts, a specific attention must be devoted to the degree of exclusivity granted to the licensee. The licensor (university) can indeed grant a license with varying degrees of exclusivity (Cameron, 2010) (see Figure 1). At one extreme of the spectrum an exclusive license gives the highest degree of exclusivity to the licensee. It indeed excludes everyone, even the licensor, from the use of the technology (often the licensor includes a clause in the contract which states that it can continue to perform research after the grant of the exclusive license). In this sense, an exclusive license is therefore very similar to a sale of the patent. An important consequence of exclusive license is that, since the university grants a license to only one firm, this firm will enjoy a monopoly position over the use and commercialization of the invention.

Figure 1 – Degrees of exclusivity in the exploitation of research results

Open source license → Publication → Non-exclusive license → Semi-exclusive license → Exclusive license

DEGREE OF EXCLUSIVITY
At the other extreme of the spectrum open source licenses represent the less exclusive form of licensing. Here, everyone can use the licensed invention and contribute to the improvement of that invention provided that the others can also use or modify these improvements without any permission (Gambardella, Hall, 2006). We usually see such open source copyright licensing in the case of software. Yet, since open source licensing is very specific and still rare in the case of patents we will not consider it in this paper. What we will consider instead, even if from a legal point of view it is not a license, is the case when the university chooses to publish its research results. Indeed, before it chooses its licensing strategy the university must decide whether it patents or publishes the invention. It is only if it decides to patent that it will have to think about the licensing regime. In case the university decides to publish the invention, it enters the public domain, i.e. it can be used by everybody without having to pay and to ask permission to the inventor. We need to consider this possibility of publication because we believe that it does not make sense to disconnect it from the decision to patent and to license the invention. In our framework which is about the degree of exclusivity in the exploitation of research results, scientific publication (even if not being formally a license) stands therefore just in between open source license and non-exclusive license (it is less open than the former but more open than the latter).

In between those two extremes, many different degree of exclusivity can be envisaged. Universities can, for instance, grant non-exclusive license, which means that they can grant a license to many different firms at the same time. This type of licensing contract grants no exclusivity to companies which may therefore allowing competitors also to obtain a license, thus increasing competition in the market. University may also grant licenses which are exclusive per field of use or exclusive per territory (this is what is called semi-exclusive license in Figure 1).

In the first case the company is granted exclusivity for one specific use or one specific sector and the university can still grant license to other companies for other uses or sectors. Limiting the use of software licenses to a particular machine or limiting the sale of a drug that has several therapeutic indications, to the pre-determined indication can be given as an example to this type of restriction (Cameron, 2010). In the second case the company is granted exclusivity for one territory but the university can still grant license to other companies in other places. The territory may be limited to particular country, region or specified location. In this case, the firm that is restricted by territory cannot sell the product outside of the pre-determined geography. Finally, university can also grant exclusive license but for a limited time. At the end of the license period the university can thus decide
to grant licenses, exclusive or not, to other companies. In all these cases an invention can therefore be exclusively licensed multiple times (Lemley, 2007; Thursby, Thursby, 2007; Pénin, 2010a).

The decision to grant an exclusive versus non-exclusive or semi-exclusive license or versus publishing the research results may have important implications on the performance of the transfer of the technology. However, as suggested by the three following examples, each type of license can be successful, according to the context.

**A Successful Case of Exclusive License**

Although exclusive licensing may induce monopoly deadweight loss and block future innovations, in some cases they are necessary in order to transfer the invention, i.e. in order to provide firms with incentives to invest in the further development of the invention. This point was emphasized, for instance, by Colyvas et al. (2002) who displayed the case of an invention, of which the authors could not reveal the name (invention B in their paper), which was a therapeutic treatment for common eye disease (it was a proof of concept, i.e. still quite far from the market). Due to the originality of the invention (few scientists thought that it could work) and to its embryonic nature, the TTO of the university had difficulties in finding a company willing to buy a license. Eventually, a company accepted to do so but only if exclusivity was granted to her. After a couple of years and common efforts between both the inventor and the company, the therapy finally obtained FDA approval and hit the market, thus yielding important revenues for the firm, the university and the inventor\(^2\).

More generally, exclusive licenses are usually considered as absolutely necessary in the case of pharmaceutical products. Indeed, a new drug invented by a university must still go through a big number of tests; preclinical, clinical, etc., and those tests are very costly. Usually firms are reluctant to invest in order to perform those tests without the guaranty of having a monopoly on the drug market, i.e. without having received an exclusive license (Mansfield, 1986; Levin et al., 1987). As an illustration, a recent survey on French public scientists has showed that, in the case of drugs, scientists who have had one of their invented drug transferred to a company

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\(^2\) Interestingly, even if this case stresses the importance of exclusive license in order to incentivize firms, it also puts forward some of the risks of this type of license. Indeed, even after the therapy became a success, Colyvas et al. explain that the inventor was still concerned by the fact that: “all of possible avenues for treatment were not explored, and that the treatment is unnecessarily costly for consumers” (2002, p. 69).
all consider that without an exclusive license this transfer would not have been made possible (Pénin, 2010b). This unanimity must be compared with the case of other sectors, engineering science for instance, in which most scientists do not believe that exclusivity is necessary to transfer their invention.

**A Successful Case of Non-Exclusive License**

A famous example where a non-exclusive license enabled the wide diffusion of a technology is Cohen-Boyer technology on recombinant DNA (rDNA) products. In 1973, Stanley Cohen (Stanford University) and Herbert Boyer (University of California in San Francisco) developed the rDNA technology and a patent was quickly applied for by Stanford University in 1974 and was granted in 1980 (other patents did follow on some extensions of the technology). Given the generic nature of the technology, which had many applications in most of the life science sectors (biotechnology, pharmaceutical, chemical, agriculture, food, energy etc.), the University of Stanford decided to adopt a non-exclusive licensing strategy, i.e. they decided to grant a license to any firm which would like to get one at a modest price.

This strategy did not prevent the transfer of the technology to the industry, nor did it imply lower revenue for Stanford. Actually, during the 17 years where the different patents held by Stanford were in force Cohen-Boyer technology was non-exclusively licensed to 468 companies and to the end of 2001 Stanford University generated US$254 million. Furthermore, 2442 new products were developed based on rDNA technology by the time patent expired and commercial products developed by licensees generated US$35 billion (Feldman et al., 2005; Feldman et al., 2007). According to Feldman et al. (2007), Stanford’s decision to rely on a non-exclusive strategy was decisive to explain the large diffusion of the technology. Would the technology have been licensed exclusively to a single company, it is possible that the rise of biotechnology industry would have been delayed for years.

**A Successful Case of Mixed License**

*(exclusivity limited in time and then non-exclusivity)*

The historical example of the invention of insulin by the University of Toronto illustrates the role of mixed licensing strategy in order to valorise a technology. In this case an exclusive license limited in time has proved necessary in order to induce a company to invest in the transfer of the technology. But, in addition, open source-like licenses have, after the period of
exclusivity, ensured a wide diffusion of the technology and of its improvements.

In 1922, university of Toronto got a patent on insulin and its manufacturing methods (Cassier, Sinding, 2008). Insulin is an invention with an important social value and the University of Toronto did not want to give a monopoly over this invention to a single firm. They hence decided to opt for non-exclusive license with grant-back mechanisms which make this licensing scheme very close to open source licenses (Pénin, 2011). Indeed University of Toronto decided to make not only the technology available to everybody but also its future improvements. To do so it relied on grant-back mechanisms made possible by the patent it owned and which obliged licensees which improve the licensed technology to share their improvements with the University of Toronto and with other licensees. In a sense University of Toronto developed what we call today an “open patent pool” (Cassier, Sinding, 2008). Yet, conscious about the fact that industrialists needed incentives to invest in this still uncertain technology they first granted an exclusive license for one year to Eli Lilly. Given the embryonic state of the invention, which was still in experimental phase and industrial scale tests were necessary, this one year exclusivity was apparently necessary for Eli Lilly to accept to invest in the further development of the invention. But after this one year exclusivity, the University of Toronto did license non-exclusively the invention and its improvements in an open way to many other companies.

To Summarize

As shown by those examples, there is no systematic licensing scheme that guarantees successful technology transfer. The success of a given strategy depends largely on the context and, in particular, on the nature of the invention. Exclusive licenses may be required in order to induce firms to invest in the development of embryonic, far from the market, invention. But on the other hand non-exclusive licenses or publication of research results foster competition and the use of the technology by many firms and in many sectors (exclusive license induce monopoly deadweight loss). It may therefore also avoid the risk that the technology is never transferred. As to the revenue for the university, an exclusive license usually yields higher royalty rates in the short run. But non-exclusive licenses, if they are sufficiently numerous, can yield higher total amount (even if less per license). In the next section we develop a formal model in order to capture some of the elements put forward above and to understand better how the different variables interact with each other.
A MODEL TO ANALYSE THE EFFECT OF THE NATURE OF THE INVENTION ON THE PERFORMANCE OF TECHNOLOGY TRANSFER

Main Settings of the Model

We consider a sequential game with 5 players consisting of 1 university and 4 firms. Furthermore, we assume that two firms (F_{1A} and F_{2A}) are operating in an industry A and the other two (F_{1B} and F_{2B}) in an industry B. We also assume that the university has made a product invention that she would like to transfer to the firms so that they can sell it on their market. The two inverse demand functions for this invention are: \( p_A = 1 - q_A \) in the market A and \( p_B = 1 - q_B \) in the market B (this means that we consider two markets with the same size). The timing of the game is as follows: In the first stage, university decides either to publish or patent the invention. If university decides to patent, in the second stage, it must decide to license the invention either exclusively, non-exclusively or exclusively per field of use\(^3\). Then, at the last stage of the game, firms must decide whether or not to invest in order to be able to sell the invention and make money out of it.

Hence we have four possible outcomes of the game: 1) the invention is not commercialized in the two industries (the four firms do not want to invest, i.e. the technology remains on the shelves of the university); 2) the invention is exclusively commercialised by one firm (global monopoly case); 3) the invention is licensed exclusively per field of use to firms F_{1A} in industry A and F_{1B} in industry B and; 4) the invention is non-exclusively licensed or published, i.e. it becomes available to all the four firms which all decide to adopt it. In this latter case we assume that the firms compete à la Cournot in their respective sector.

In the case where the invention is patented and licensed we consider the following licensing fee: Total fee (TF) is a function of the royalty rate \( t \), i.e. the fee per unit of output \( q \) where \( 0 < t < 1 \). For simplicity we assume that there is no fixed fee\(^4\). Royalty rate is exogenous and differs when the license is exclusive \( (t_e) \), non-exclusive \( (t_{ne}) \) or exclusive per field of use \( (t_{efu}) \) such

\(^3\) In the case of an exclusive license we assume by convention that the licensee is firm 1, i.e. firm F_{1A} in sector A and F_{1B} in sector B. We also assume that there is no possibility of sublicensing for the licensee, i.e. the latter cannot grant licenses to other firms.

\(^4\) In reality, many licensing agreements between university and firms do contain a lump-sum, i.e. a fixed part. However, in the model the presence of a fixed part does not significantly affect our results at the equilibrium of the game. We can therefore remove it without any loss of generality.
that: $0 < t_e < t_{efu} < t_f < 1^5$. In addition, we assume that $t_{efu}, t_{efu}$ and $t_f$ are such that licensees’ profits are always positive. Similarly, in order to make sure that licensee’s monopoly profit is always higher than the duopoly profit we posit that $t_e < \frac{1+2t_{efu}}{3}$. Furthermore, without loss of generality we can also consider that firms’ marginal cost (MC) are zero, i.e. when the firm buys a license, the marginal cost equals the royalty rate of the license to the university.

When university patents the invention it bears a cost (e.g. patent application fee, labour cost, etc.) associated with patenting, denoted by $c_p$. University decides to patent the invention only if its net income (i.e. royalty revenues minus patenting costs) is positive. In the other case it decides to publish. In other words, we assume that the objective function of the university is to maximize its net income, irrespective of the implications on social welfare$^6$. Similarly, firms accept to invest in the development and commercialisation of the invention only if it yields them positive profits.

In this model, we are specifically interested by the influence of the nature of the invention that we consider along two dimensions: (1) Distance to the market and (2) Specificity.

– Distance to the market indicates whether the invention is embryonic (far from the market) or mature (close to the market). An embryonic invention means that firms must still invest in its development before they can make money out of it. A mature invention means that it is immediately usable by firms without further investments$^7$. In the model, we capture the embryonic versus mature nature

5. The fact that $t_{efu} < t_e$ may be justified by some degree of permeability between industries A and B. If the two industries were perfectly impermeable, i.e. if an exclusive license per field of use was enforceable at no cost, then we should have $t_{efu} = t_e$. But, when the enforcement of an exclusive license per field of use is costly, firms may be willing to pay more in order to have a global exclusive license.

6. If this assumption may be too strong in some cases, it is undisputable that universities increasingly face pressures from policy makers in order to be more “profitable”. Also, recent reforms in most developed countries tend to delegate the mission of technology transfer to independent TTOs (example SATT in France) whose objective is more or less explicitly to be profitable. It is therefore not exaggerated to assume that the revenues generated by technology transfer are an important issue either for universities, for TTOs or for both.

7. According to Jensen and Thursby (2001), most university inventions are at embryonic stage, i.e. either are proof of concepts or lab-scale prototypes, thus justifying the grant of exclusive licenses to firms. They conducted a survey on 62 U.S. research universities which showed that over 75 percent of the university inventions were at embryonic stage and only 12 percent were ready for commercial use at the moment of the patent. Also, 31 percent of these inventions were licensed either exclusively or exclusively per field of use whereas only 10 percent non-exclusively licensed. Furthermore, a recent inventor survey on the characteristics of 80 inventions
of the invention by introducing a parameter \( I \) which indicates the amount of investment that a company must perform before she can sell the invention. For simplicity we assume that \( I \) is a fixed cost, i.e. if the invention is embryonic, the total cost (TC) function of the firm becomes \( TC = t q + I \). If \( I = 0 \) then the invention is mature; the higher \( I \), the more embryonic the invention.

– An invention can also be specific or generic. A generic invention (general purpose technology) may be used in many different applications and sectors. Conversely, a specific technology can only be used for a particular application or in a particular sector. In the model we consider that a generic invention can be used in the two sectors A and B whereas a specific invention can only be used in sector A (it has no application in sector B).

### The Case of a Specific Technology

By convention a specific invention can be used only in industry A. The game is hence reduced to three players (university and firms 1 and 2 in industry A). In this case it is immediate to stress a first result.

**Proposition 1:**

(a) If the invention is too embryonic \( (I > \frac{(1-t_e)^2}{4}) \), it does not exist a SPNE in which the invention is commercialized; 
(b) If the invention is moderately embryonic \( \left( \frac{(1-t_e)^2}{9} < I < \frac{(1-t_e)^2}{4} \right) \) then the only SPNE of the game which enables the invention to be commercialized is when the university delivers an exclusive license. This equilibrium is reached if and only if \( t_e \frac{(1-t_e)}{2} > c_p \); 
(c) If the invention is mature \( (0 \leq I < \frac{(1-t_m)^2}{9}) \), then there always exists a SPNE in which the invention is transferred.

This first proposition is in line with the discussion in section 2. The more embryonic the university invention the more likely it is to see exclusive

licensed by two French universities (University of Strasbourg and University of Grenoble-Alpes) reveals that 65 percent of the inventions were considered to be at embryonic stage (i.e. either embryonic or moderately embryonic) whereas 35 percent are mature (i.e. close to the market). 86 percent of the embryonic inventions were licensed either exclusively or exclusively per field of use. Nevertheless 71 percent of the inventions that were considered as mature were also licensed either exclusively or exclusively per field of use even if no further investment or only a little additional investment is needed, which may indicate the creation of unnecessary monopolies (Ocalan-Ozel, Penin, 2016).
licensing. Indeed, since duopoly profits are lower than monopoly profits, it is possible that publishing the invention or granting non-exclusive licenses to firms do not provide them with enough incentives to invest in the development of the technology. Yet, when the invention is too embryonic even the grant of an exclusive license is not sufficient to induce firms to invest in the development of the invention.

Indeed, if \( I > \frac{(1-t_e)^2}{4} \) then at the last stage of the game, firms will never decide to commercialize the invention because it would always yield them negative profits. Furthermore, if \( \frac{(1-t_w)^2}{9} < I < \frac{(1-t_e)^2}{4} \) then firms’ duopoly profits are always negative, i.e. firms never accept to commercialize the invention if it is not exclusively licensed. But because the monopoly profit is positive, under exclusive licensing scheme firm 1 accepts to commercialize the invention (provided that \( 0 < t_e < \frac{1}{3} \)). Furthermore, the university accepts to patent and delivers an exclusive license to firm 1 if and only if \( t_e \frac{(1-t_e)}{2} > c_p \). Finally, if \( I < \frac{(1-t_w)^2}{9} \) then both monopoly and duopoly profits are positive and firms always accept to commercialize the invention. Hence under both cases, the technology is transferred. University may choose either to patent or publish depending on its net income. If the cost of patenting is lower than the licensing revenue, that is to say either \( c_p < t_e \frac{(1-t_e)}{2} \) or \( c_p < 2 t_w \frac{(1-t_w)}{3} \), then at the SPNE of the game university patents and grants either an exclusive or a non-exclusive license. But, on the other hand, if the cost of patenting is higher than the licensing revenue, that is to say both \( c_p > t_e \frac{(1-t_e)}{2} \) and \( c_p > 2 t_w \frac{(1-t_w)}{3} \), then at the SPNE of the game the university publishes the invention.

In other words, when the technology is mature it will be transferred in any case. Whatever the choice of the university, firms decide to commercialize the invention. Yet, all the SPNE of the game may not be in the public interest. This is clearly stated by proposition 2.

Proposition 2: Assume \( I = 0 \) (invention is mature). In this case the social surplus is the highest when the invention is published. But, if \( c_p < t_e \frac{(1-t_e)}{2} \) or...
In order to show whether the publishing gives the highest social surplus when the invention is mature, we should compare social welfare (SW) under each valorisation regime. Table 2 summarizes these findings. We see that SW under publishing is always higher than SW under non-exclusive and exclusive licensing if the invention is mature. However, if $c_p < t_e \left( \frac{1-t_e}{2} \right)$ or if $c_p < 2t_{ne} \left( \frac{1-t_{ne}}{3} \right)$, the university net income will be higher under patenting than under publishing, i.e. the university will decide to patent and to deliver an exclusive or non-exclusive license, although it is socially under optimal.

The Case of a Generic and Mature Technology

In the case of a generic technology the university invention can be used in the two industries A and B and can thus be commercialized by the 4 firms in those two industries. A first immediate result is stated in proposition 3 below.

Proposition 3: If the invention is generic and mature ($I = 0$) then there always exist a SPNE in which the invention is commercialized at least in one sector.

Indeed, if the invention is mature, then both monopoly and duopoly profits are positive in each sector. Hence firms always accept to commercialize the invention whatever the strategy of the university (patenting or publishing) is. If the university decides to patent, provided that $2t_{efu} \left( \frac{1-t_{efu}}{2} \right) > t_e \left( \frac{1-t_e}{2} \right)$ or $4t_{ne} \left( \frac{1-t_{ne}}{3} \right) > t_e \left( \frac{1-t_e}{2} \right)$, the university always chooses not to give a global exclusivity to a single firm, thus leading to the commercialization in both sectors. Yet, if those two conditions do not hold, then the university will decide to deliver a global exclusive license to only one firm, thus leading to commercialization only in sector A. Such a situation might therefore be inefficient as stated in proposition 4.

Proposition 4: If the invention is generic and mature, the SPNE which yields the highest social surplus is when the invention is published. But if $c_p < t_e \left( \frac{1-t_e}{2} \right)$, $c_p < 2t_{efu} \left( \frac{1-t_{efu}}{2} \right)$ or $c_p < 4t_{ne} \left( \frac{1-t_{ne}}{3} \right)$, then the university decides to patent the
Table 2 — Social Welfare under Different Licensing Strategies
(Specific Invention)

<table>
<thead>
<tr>
<th>Licensing Strategy</th>
<th>Social Welfare</th>
<th>Firms’ Profit</th>
<th>Consumer Surplus</th>
<th>University Net Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive Licensing</td>
<td>$\frac{3}{8}(1-t_c)^2 - I + t_c\left(\frac{1-t_c}{2}\right) - c_p$</td>
<td>$\frac{1}{4}(1-t_c)^2 - I$</td>
<td>$\frac{1}{8}(1-t_c)^2$</td>
<td>$t_c\left(\frac{1-t_c}{2}\right) - c_p$</td>
</tr>
<tr>
<td>Non-exclusive Licensing</td>
<td>$\frac{4}{9}(1-t_{nc})^2 - 2I + 2t_{nc}\left(\frac{1-t_{nc}}{3}\right) - c_p$</td>
<td>$\frac{2}{9}(1-t_{nc})^2 - 2I$</td>
<td>$\frac{2}{9}(1-t_{nc})^2$</td>
<td>$2t_{nc}\left(\frac{1-t_{nc}}{3}\right) - c_p$</td>
</tr>
<tr>
<td>Publishing</td>
<td>$\frac{4}{9} - 2I$</td>
<td>$\frac{2}{9} - 2I$</td>
<td>$\frac{2}{9}$</td>
<td>0</td>
</tr>
</tbody>
</table>
invention, i.e. the SPNE of the game is not socially optimal. The less efficient SPNE is when \( t_e \left( \frac{1-t_e}{2} \right) > 2t_{elu} \left( \frac{1-t_{elu}}{2} \right) \) and \( t_e \left( \frac{1-t_e}{2} \right) > 4t_{nc} \left( \frac{1-t_{nc}}{3} \right) \), i.e. when the university chooses to grant an exclusive license only to one firm in one sector.

In order to show whether publishing gives the highest social surplus when the invention is generic and mature we must again compare SW under each valorisation regimes. Table 3 summarizes these findings. We see that SW under publishing is higher than SW under exclusive licensing, exclusive license per field of use and non-exclusive licensing. However, if either \( c_p < t_e \left( \frac{1-t_e}{2} \right) \) or \( c_p < 2t_{elu} \left( \frac{1-t_{elu}}{2} \right) \) or \( c_p < 4t_{nc} \left( \frac{1-t_{nc}}{3} \right) \), university decides to patent (i.e. publishing cannot be a SPNE), leading hence to inefficiency. Furthermore, it is possible that the invention is not commercialized in both sectors if university exclusively and globally license the invention to firm 1 in sector A. University may choose to give a global exclusivity if both \( t_e \left( \frac{1-t_e}{2} \right) > 2t_{elu} \left( \frac{1-t_{elu}}{2} \right) \) and \( t_e \left( \frac{1-t_e}{2} \right) > 4t_{nc} \left( \frac{1-t_{nc}}{3} \right) \). Intuitively, the inefficiency is higher under global exclusivity since the quantity produced decreases and the invention cannot be commercialized in both sectors.

The Case of a Generic and Moderately Embryonic Technology

A last set of results is obtained when the invention is generic and moderately embryonic. In this case, as stated by proposition 5, some degree of exclusivity may be necessary in order to induce firms to invest in the technology.

Proposition 5: If the invention is generic and moderately embryonic then the only SPNE which allows the invention to be commercialized in both sectors is when the university decides to patent and to deliver exclusive license per field of use. This SPNE is possible if \( 2t_{elu} \left( \frac{1-t_{elu}}{2} \right) > c_p \) and \( 2t_{elu} \left( \frac{1-t_{elu}}{2} \right) > t_e \left( \frac{1-t_e}{2} \right) \).

Indeed, if the invention is moderately embryonic firms’ duopoly profits, whether university publishes or delivers a non-exclusive license, are always negative and firms never accept to commercialize the invention (see proposition 1). Although global exclusivity may allow commercialization in sector A, it will not be possible to have a SPNE which allows the invention to be commercialized in both sectors. Therefore, it is only when firms obtain a monopoly situation in their respective markets (exclusivity per field of
### Table 3 – Social Welfare under Different Licensing Strategies (Generic and Mature Invention)

<table>
<thead>
<tr>
<th>Licensing Method</th>
<th>Social Welfare</th>
<th>Total Profit</th>
<th>Consumer Surplus</th>
<th>University Net Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive Licensing</td>
<td>( \frac{3}{8}(1 - t_c)^2 + t_c\left(\frac{1 - t_c}{2}\right) - c_p )</td>
<td>( \frac{1}{4}(1 - t_c)^2 )</td>
<td>( \frac{1}{8}(1 - t_c)^2 )</td>
<td>( t_c\left(\frac{1 - t_c}{2}\right) - c_p )</td>
</tr>
<tr>
<td>Exclusive Licensing per Field of Use</td>
<td>( \frac{3}{4}(1 - t_{e/u})^2 + 2t_{e/u}\left(\frac{1 - t_{e/u}}{2}\right) - c_p )</td>
<td>( \frac{1}{2}(1 - t_{e/u})^2 )</td>
<td>( \frac{1}{4}(1 - t_{e/u})^2 )</td>
<td>( 2t_{e/u}\left(\frac{1 - t_{e/u}}{2}\right) - c_p )</td>
</tr>
<tr>
<td>Non-exclusive Licensing</td>
<td>( \frac{8}{9}(1 - t_{n/o})^2 + 4t_{n/o}\left(\frac{1 - t_{n/o}}{3}\right) - c_p )</td>
<td>( \frac{4}{9}(1 - t_{n/o})^2 )</td>
<td>( \frac{4}{9}(1 - t_{n/o})^2 )</td>
<td>( 4t_{n/o}\left(\frac{1 - t_{n/o}}{3}\right) - c_p )</td>
</tr>
<tr>
<td>Publishing</td>
<td>( \frac{8}{9} )</td>
<td>( \frac{4}{9} )</td>
<td>( \frac{4}{9} )</td>
<td>0</td>
</tr>
</tbody>
</table>
use) that they are willing to commercialize the invention. Furthermore, the university accepts to patent and deliver exclusive license per field of use if and only if \(2t_{efu} \left(1 - t_{efu}\right) > c_p\) and \(2t_{efu} \left(1 - t_{efu}\right) > t_r \left(1 - t_e\right)\). However, it is also possible that universities do not choose this licensing contract (because it does not maximize their revenues), as stated by proposition 6.

**Proposition 6:** If the invention is generic and moderately embryonic and if \(t_r \left(1 - t_e\right) > 2t_{efu} \left(1 - t_{efu}\right)\), the only SPNE is when the university delivers a global exclusive license, i.e. the invention is commercialized only in sector A which is clearly inefficient.

**Summary of the Results**

The main results of the model are summarized below and in Table 4:

- If the invention is too embryonic and either specific or generic, there is no SPNE in which the technology can be transferred.
- If the invention is moderately embryonic and specific, the only way of transferring the technology is when the university delivers an exclusive license to a firm.
- If the invention is moderately embryonic and generic, then the only way of transferring the technology in both sectors is giving exclusive license per field of use. If university decides to give a global exclusivity, this may lead to inefficiency. This case cannot be excluded under some reasonable conditions.
- If the invention is mature and specific or generic, there always exists a SPNE in which the technology is transferred in all sectors. In this case the optimal strategy is always publishing. However university may choose to patent if \(c_p\) is lower than its licensing revenue.
- Finally, if the invention is mature and generic, it is possible (under some extreme conditions) that the university chooses to grant a global exclusive license, thus leading to an under commercialization of the technology as compared to the optimum.

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8. Note that this result holds under the assumption that licensees have no right to deliver sub-license. Without this assumption it would be possible for firm \(F_{1A}\) to sell an exclusive license per field of use to firm \(F_{1B}\).
CONCLUSION

The growing interest of the “ivory tower” in valorising its research through patenting and licensing has raised many questions. In this paper we have investigated how the nature of the invention (embryonic versus mature; generic versus specific) may affect the patenting strategy of universities and the degree of exclusivity of the licensing contract. We have shown that in some cases delivering an exclusive license is the optimal strategy (for instance when the invention is embryonic) but that in other cases more open strategies based on publication or non-exclusive licenses are preferable. We have also shown that it may be possible that universities choose to grant licensing contracts which are not in the public interest. This paper hence contributes to the existing literature in offering a conceptual understanding on how the nature of the invention should shape PROs intellectual property patenting and licensing strategy.

Some of the findings of our model are clearly in line with recent policy evolutions. For instance, in line with the Bayh Dole argument, we find out that some degree of exclusivity may be desirable when the invention is embryonic (and clearly many university inventions are embryonic). Also, we find out that even exclusive licenses may not be sufficient to transfer the technology if the latter is too embryonic and hence too costly. Thus, in this case policy measures that favour academic entrepreneurship, creation of start-up, and/or the collaboration between the academic inventor and the firm might help to develop the technology and transfer the invention (Jensen, Thursby, 2001).
However, our model also points out some possible source of inefficiency if universities decide to rely systematically on exclusive licenses. In particular this may be detrimental to social welfare when the invention is mature or generic. In this case, an important finding of the model is that more open, non-exclusive licensing strategies may be the most desirable solution. This result must be emphasized, in particular since budget constraints that apply to countries all around the world may induce governments to increasingly require PROs to “sell” their technologies irrespectively of their nature and of the impact on social welfare. This short run strategy might sometimes reduce non-exclusive valorisation strategies and be detrimental on the longer run to social welfare.

Further research will follow at least two lines of inquiry. First, it will be needed to broaden our theoretical analysis and to consider more sophisticated situation which have been voluntary excluded in this simple analysis. For instance, one needs to pay more attention to the formation of the royalty rate (which was considered as exogenous here). In practice licensor and licensee negotiate this rate and the modelling of this negotiation might change the results of our model. In the same vein, we did not consider the issue of asymmetry of information, we did not consider the existence of a budget constraint for PROs which may prevent them from patenting their research result and we did not explore the impact of two markets of different sizes. All those elements can obviously change some of the results obtained in this paper. Similarly, it might be interesting to focus on other determinants of PROs licensing strategy. In this work, we only considered the effect of the nature of the invention. In addition to this, the effects of other parameters (technological regime, size of market, characteristics of licensee firm, etc.) may also be explored. Further, the research valorisation analysis may also be extended to other contractual forms such as informal or formal collaborations or material transfer agreements.

Second, our theoretical work needs to be completed by an empirical analysis. This is a challenging point since micro data as regard to research licensing contracts are not easily available. A first attempt has been made recently by Ocalan-Ozel and Pénin (2016) who study all the licensing contracts of two leading French scientific universities and try to understand the determinants of the exclusive versus non-exclusive dimension of the license. In particular, they make a link with the nature and property of the invention which is licensed (whether or not it is embryonic versus mature, generic versus specific, appropriable versus non-appropriable, complex versus simple, etc.). Their results seem to indicate that, as suggested in this paper, the licensing strategy which is effectively implemented might not always be in line with the public interest (mature and generic inventions are sometimes
exclusively licensed for instance). Due to the growing importance of PROs patenting and licensing and to the lack of empirical evidence, we believe that this type of empirical analysis should be deepened in the future.

REFERENCES


