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Invention Characteristics and the Degree of Exclusivity of University Licenses: The Case of Two Leading French Research Universities

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Abstract

This paper examines the determinants of university exclusive versus non-exclusive licenses. We specifically focus on the effect of the characteristics of the licensed invention (i.e. stage of development, specificity and appropriability). We rely on a unique and original dataset of 91 inventions contained in 62 intellectual property licensing contracts executed in the period of 2005-2014 by two leading French research universities. We cannot find a significant relation between the characteristics of the invention and the degree of exclusivity. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. Furthermore, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. These results, although still exploratory, contribute to feed the discussion about the performance of university-industry technology transfer since they suggest that performance might be improved by taking more into account the characteristics of the licensed invention.

Key words: University licensing; technology transfer; invention characteristics; degree of exclusivity

JEL Classification: O31, O32, O34

Abstract

This paper examines the determinants of university exclusive versus non-exclusive licenses. We specifically focus on the effect of the characteristics of the licensed invention (i.e. stage of development, specificity and appropriability). We rely on a unique and original dataset of 91 inventions contained in 62 intellectual property licensing contracts executed in the period of 2005-2014 by two leading French research universities. We cannot find a significant relation between the characteristics of the invention and the degree of exclusivity. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. Furthermore, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. These results, although still exploratory, contribute to feed the discussion about the performance of university-industry technology transfer since they suggest that performance might be improved by taking more into account the characteristics of the licensed invention.

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1. Introduction

Universities are the key organizations that generate and disseminate scientific knowledge widely, and university knowledge is a substantial resource for industrial innovation and economic growth (Veugelers and Del Rey, 2014). There exist diversity of formal and informal channels, through which universities can transfer their technology and knowledge to the industry and hence contribute to the economy (D'Este and Patel, 2007; Bodas-Freitas *et al.*, 2013; Perkmann *et al.*, 2013). Although, historically, university-industry interaction relies more on informal mechanisms, it has become more institutionalized in the last few decades (Geuna and Muscio, 2009). Increasing scale and complexity of the transfer activities paved the way to the establishment of intermediary structures, such as technology transfer offices (TTOs). TTOs are mostly dedicated to managing the patenting and licensing activities on behalf of universities, with the increasing scale and complexity of these activities.

The last three decades have witnessed a worldwide boom in university patenting and licensing (Mowery *et al.*, 2004; Geuna and Nesta, 2006; Lissoni *et al.*, 2008; Siegel and Wright, 2015). But despite many statistics as to the number of university patents, number of licenses delivered to firms, amount of royalties collected by universities (Thursby *et al.*, 2001; Siegel *et al.*, 2003; Roessner *et al.*, 2013), estimated number of spin-offs or start-ups (Powers and McDougall, 2005; Van Looy *et al.*, 2011) and jobs created, little is known about the content of the licensing contracts and its consequences on the transfer. Yet, licensing contracts are not homogeneous (Bessy *et al.*, 2002) and their characteristics might have important implications on the performance of the transfer of the technology.

A typical licensing contract includes clauses on the parties involved, length of the contract, patents to be exploited, exclusivity and restrictions, remuneration scheme, existence of grant-back mechanism, etc.(Anand and Khanna,2000; Bessy *et al.*, 2002). Among many different clauses contained in the contract, degree of exclusivity granted to the licensee requires a specific attention (Öcalan-Özel and Pénin, 2016). The licensor (university in our case) can grant a license to the licensee (firm in our case) with varying degrees of exclusivity (Anand and Khanna, 2000; Cameron, 2010). Exclusive license represents the highest degree of exclusivity. It gives a monopoly right to the licensee over the use of an invention by excluding everyone else (even the licensor) from using it. On the other hand, open-source licensing is the least exclusive form of licensing since everyone can use and modify the invention or contribute to its development, without any permission, in return

for similar rights attached to the improvements (e.g. general public license (GPL) for software inventions) (Scotchmer, 2010). In between these two extreme forms of licensing, different degrees of exclusivities can also be granted to firms. For instance in the case of non-exclusive licensing, many different firms can receive a license over the use of an invention at the same time. Furthermore, universities may also grant exclusive licenses which are restricted by field of use, by territory or limited in time which we may refer as restricted exclusivity or semi-exclusive license (Anand and Khanna, 2000; Cameron, 2010).

The degree of exclusivity of the license may have important implications on the performance of the transfer of the invention and, in turn, on social welfare (Mazzoleni, 2006). On the one hand, granting an exclusive license might be necessary in order to provide firms with incentives to invest in the development of the invention. This might be especially the case for embryonic inventions which are far from being a marketable product (Jensen and Thursby, 2001; Thursby and Thursby, 2007; Dechenaux *et al.*, 2011; Mowery and Ziedonis, 2015). On the other hand, an exclusive license also generates a monopoly deadweight loss for society. Depending on the context, an exclusive license might therefore induce an unnecessary monopoly deadweight loss when, for instance, exclusivity is not required to provide firms with incentives. Alternatively, in other cases non-exclusive licenses might not provide enough incentives and thus might not ensure the transfer of the invention that remains on the shelves of the university lab (Pénin, 2010).

Given the aforementioned heterogeneity of possible exclusivity clauses, the objective of this paper is to provide a first investigation into the determinants of universities' exclusive versus non-exclusive licenses. In particular we are interested in the role of the invention's characteristics, i.e. how the properties of the invention shape the exclusive versus non-exclusive nature of the license. Many dimensions might indeed influence the choice of a university license¹. For instance, Jensen and Thursby (2001) show that the embryonic nature of the invention may explain the exclusivity granted to the licensee firm. Pénin (2010) proposes that the nature of the invention (i.e. distance to market, specificity), the technological regime (i.e. appropriability, complexity, speed of technical

¹ Although in this study we assume that universities choose the degree of exclusivity, we acknowledge that this is rather an outcome of a bargaining process. However, the factors such as the perceived value of the technology by the firm, the reputation of the university or the experience of the TTOs could allow universities to be in a strong bargaining position and hence choose the degree of exclusivity. We can exemplify those cases in which universities indeed "chose" the degree of exclusivity as the licensing of the Cohen-Boyer technology by the University of Stanford (Feldman *et al.*, 2007) or the licensing of Insulin patent by the University of Toronto (Cassier and Sinding, 2008). Yet, this was also rather related to the fact that licensed technologies had a very high commercial potential.

progress) and the competition regime (i.e. size of market, intensity of competition) are important determinants of university licenses. Öcalan-Özel and Pénin (2016) develop a theoretical model where they analyze the exclusive versus non-exclusive nature of the license by taking into account two dimensions: whether the invention is embryonic versus mature and whether it is generic versus specific. With regard to empirical work, although a few studies relate certain characteristics of the technology to the selection of commercialization mode (i.e. licensing versus start-up creation) (Shane, 2004) or to the selection of business models for commercialization (Pries and Guild, 2011), to the best of our knowledge, there isn't any empirical study trying to explain the exclusive versus non-exclusive nature of university licenses based on the characteristics of the licensed invention. This might be due, among other things, to the difficulty to assess and measure the different dimensions of an invention.

This paper aims at contributing to fill this gap by providing a first empirical research, although clearly exploratory, on the impact of the properties of the licensed technology on the nature of the license. We investigate the role of the following dimensions of the licensed invention on the probability to deliver exclusive versus non-exclusive or semi-exclusive licenses: distance to the market (embryonic versus mature inventions), degree of specificity and degree of appropriability. To do so we rely on the cases of two leading French research universities (University of Strasbourg and University of Grenoble Alpes) for which we have been able to collect a unique and original dataset of 91 inventions contained in 62 licensing (and cession) contracts executed in the period of 2005-2014.

In this study, we cannot find a significant effect of the characteristics of the invention on the degree of exclusivity. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. In addition, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. These results, although they are based on a limited number of observations and call for further research in order to be generalized, imply that university-industry licensing contracts might not always be welfare enhancing. In particular, they suggest that the performance of technology transfer can be improved by taking more into account the characteristics of the licensed invention. However, while interpreting these results we should keep in mind that universities and TTOs are complex organizations that face multiple and

sometimes non-aligned objectives. This research has therefore important implications for policy makers and TTO managers.

The paper proceeds as follows. In the next section we provide the theoretical background and research propositions concerning the nature of the technology. Section 3, describes the data and methodology. Section 4 presents the main findings of econometric analysis. Section 5 concludes by discussing the policy and managerial implications of our findings and sketching directions for future research.

2. Theoretical background and research propositions

The degree of exclusivity of a license and, in turn, the performance of the technology transfer might be affected by many dimensions of the licensed invention. In this study, we focus on three dimensions: embryonic versus mature; generic versus specific; appropriable versus easily imitable. In line with Öcalan-Özel and Pénin (2016) we are looking at which type of license (more or less exclusive) leads to maximizing social surplus (to transfer the technology at a minimum cost for society) according to these three characteristics of the licensed technology. In particular, we consider two effects that should determine the type of the license. The first one deals with firms' incentives to use the technology developed by universities. Sometimes universities have to grant exclusivity to firms in order to provide them with incentives to transfer and use the technology (Somaya *et al.*, 2011; Drivas *et al.*, 2017). The other one deals with the social cost of exclusivity. An exclusive license creates monopoly power and may hinder effective diffusion of new technologies (Lemley, 2008) which in turn reduces social welfare. This second effect must be balanced with the incentive effect and, given the different characteristics of inventions, universities (provided that they seek to maximize social surplus) should choose the degree of exclusivity that both provides incentives to transfer the technology and minimizes the social cost associated with monopoly power².

2.1. Embryonic versus mature technology

² Indeed, exclusivity decision might be a result of many factors. For instance, the university may prefer to grant an exclusive license to receive higher royalties in the short-term, to support small regional industries to help them catching up with the incumbent counterparts, to promote national competitiveness, to easily monitor the licensee etc. Yet, in this study we consider the exclusivity decision as mainly a trade-off between incentivizing firms to invest and the wide dissemination of the technology even if there may exist different trade-offs for universities and businesses.

Jensen and Thursby (2001) put forward that many university inventions are at embryonic stage. Through a survey of 62 U.S. research universities' licensing activities, they showed that 75 percent of the university inventions were at embryonic stage (i.e. either are proofs of concepts or lab-scale prototypes). Furthermore most of these inventions were licensed either exclusively or exclusively per field of use (31 percent) whereas only a little share (10 percent) were non-exclusively licensed.

The embryonic dimension of university technology should have an impact on the exclusive nature of the license. An embryonic invention requires additional investment from licensee and firms might be reluctant to invest in order to make the technology operational if they do not retain exclusivity (Merrill and Mazza, 2011; Drivas *et al.*, 2017). Empirical findings (Anand and Khanna; 2000; Somaya *et al.*, 2011) are also in line with this argument since they find that, as compared to already developed technologies, allocation of exclusive rights to the licensee is more likely in the case of those early stage or prospective technologies. Without exclusivity the situation would indeed be equivalent to a public good game. Firms do not want to invest in a technology that, once operational, can be used by everybody. As mentioned by (Mazzoleni and Sampat, 2002, p. 237): “what is available to everybody is of interest to no one”³. For instance, exclusive licenses are usually crucial in the case of pharmaceutical products since a new drug requires costly and time consuming tests before coming to the market (Anand and Khanna, 2000; Lemley, 2008; Somaya *et al.*, 2011). Therefore, in the absence of such an exclusive right in the drug market, firms are usually reluctant to invest in the further development of the invention (Mansfield, 1986; Levin *et al.*, 1987).

Consequently, although exclusive licensing may induce monopoly deadweight loss and block future innovations⁴, in the case of embryonic inventions they might be 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 (Colyvas *et al.*, 2002). This argument was, in particular, at the heart of the Bayh-Dole discussion in the U.S. (Mowery *et al.*, 2004). We expect therefore a positive effect of the embryonic nature of the technology on the probability of granting an exclusive license to the licensee firm.

³ This argument is inspired by an older citation from a pioneer of technology transfer in the U.S., the chemist F.G. Cottrell who wrote in 1912: “what is everybody’s business is nobody’s business” (Cottrell, 1912, cited in Mowery *et al.*, 2004, p. 59).

⁴ It is interesting to note that, contrary to the standard argument that exclusive licensing blocks or diminishes the follow-on research, a recent study by Drivas *et al.* (2017) finds that exclusive licensing increases follow-on research by non-licensees (measured by forward citations) since the occurrence of a license sends a signal to potential innovators about further innovation possibilities in the relevant fields. This signal stems from the fact that the licensee firm realizes a financial commitment through licensing the technology and hence reveals important information to non-licensees about the commercial opportunities.

Conversely, if the invention is close to the market (i.e. mature technology), we expect university technology transfer offices (TTOs) to rely more on open licensing strategies (i.e. non-exclusive license) in order to decrease the social cost associated with unnecessary monopolies.

2.2. Generic versus specific technology

Another factor that should enter into consideration when deciding about the exclusive dimension of the license deals with the generic versus specific nature of the invention. A generic invention or enabling technology (sometimes may also be referred as general purpose technology⁵) may have several applications in many different sectors (Kim and Vonortas, 2006) whereas a specific technology (or a dedicated technology) can only be used in one very specific context (Gambardella and Giarratana, 2013). In the case of a generic invention, an exclusive license may have costly consequences on social welfare because, given the generic nature of the technology, it is impossible for one company to exploit all the possible applications. It might be possible that an exclusive licensee, who has obtained an exclusive license, delivers sublicenses in cases where it does not want to exploit the technology itself. But, still, transaction costs might impede welfare increasing deals. Therefore, since a generic technology has many applications in many different sectors, it is more efficient if it is non-exclusively licensed to many firms (Lemley, 2008). Non-exclusive licenses favor the large dissemination of the technology and its exploitation in many different cases and increase the probability that all promising applications are explored (Nelson, 2004; Hayter, 2016). On the contrary, when the technology is very specific, when it has applications in only one very limited domain, granting exclusivity to a firm is less costly for society. At the extreme, if the technology can be used only in the context of one specific firm, granting an exclusivity to this firm does not impact social welfare since, in any case, even without an exclusivity the technology does not make sense for other firms.

Non-exclusive licensing of Cohen-Boyer technology, which is one of the very well-known inventions in biomedical research based on recombinant DNA (rDNA), enabled the wide diffusion of the technology across many different fields of use (Feldman *et al.*, 2007). Stanford University applied for a patent for this rDNA technology in 1974 and the patent was granted in 1980. Over the lifespan of the patent, Stanford University non-exclusively licensed the invention to 468 companies

⁵ General purpose technology (GPT) has a pervasive feature and affects entire economy as well as pre-existing social and political structures. Some examples of GPT include steam engine, railroad, electricity, automobile, computer, internet, nanotechnology, artificial intelligence and so on (Lipsey *et al.*, 2005).

and generated US\$254 million. Thanks to its generic nature, 2442 new products were developed in sectors as diverse as biotechnology, pharmaceutical, agriculture, energy, food etc. (Feldman *et al.*, 2005; Feldman *et al.*, 2007). Had the technology licensed exclusively, it is likely that such a wide diffusion would not have been possible. For this reason, we propose that non-exclusive licensing would be more likely in the case of generic inventions.

Moreover, we also propose that inventions that are both embryonic and generic might be associated more with exclusive per field of use licenses (Öcalan-Özel and Pénin, 2016). In this case, the embryonic nature of the technology calls for an exclusive license whereas its generic dimension calls for a non-exclusive license. It is therefore possible to rely on an exclusive license per field of use, i.e. a license that grants exclusivity to licensees, but only in a specified domain. The university can thus grant as many exclusive licenses as fields of use. This type of license might provide incentives to licensees since it gives them exclusivity in their own field of use while ensuring a wide dissemination of the technology across other fields of use (Somaya *et al.*, 2011).

2.3. Appropriability of the technology

The appropriability regime depicts the ease of imitation of an invention (Nelson and Winter, 1982; Teece, 1986). We say that appropriability is strong when the invention is difficult to replicate (Teece, 2003). The question of the appropriability of a technology goes beyond the simple patent issue (Teece, 1986). Many parameters affect the possibility for a firm to imitate: the existence of a patent but also the tacit nature of the knowledge base, the existence of complementary assets, the distance to the technological frontier (protection due to lead-time), etc. All these parameters explain why the cost of imitation remains often high even though the invention is not protected by a patent. Imitative firms must invest in their absorptive capacity (Cohen and Levinthal, 1989). Also, this explains why some innovative companies sometimes choose not to rely on patents in order to prevent imitation (Levin *et al.*, 1987; Cohen *et al.*, 2000). They find alternative ways of protection.

In the case of university licensing this means that if the technology is easily appropriable without patents, i.e. difficult to imitate because intense in tacit knowledge for instance or protected by the existence of complementary assets, then licensees might not need an exclusive legal right in order to find incentives to transfer and use the technology (Colyvas *et al.*, 2002). Licensees might need some assistance from the university (for instance, some help from academic researchers in order to

transfer the tacit knowledge associated with the invention) but an exclusive license might not be necessary in order to provide them with incentives. On the contrary, in a weak appropriability regime, licensee firm faces the risk of infringement by third parties and incentives to develop the licensed technology is reduced (Lee *et al.*, 2017). Therefore, when the university invention is easily imitable, licensees might need an exclusive license in order to find it profitable to exploit the technology. Thus, we propose that exclusive licensing would be less likely when the inventions are subject to a strong appropriability regime (i.e. difficult to imitate).

3. Data and methodology

The empirical analysis was carried out within the framework of COCON project (COhort of CONtracts), financed by the French National Research Agency (ANR). COCON is a multidisciplinary project conducted by researchers in economics, management and law. We have collected information about all the licensing contracts executed between 2005 and 2014 by the University of Strasbourg and the University of Grenoble Alpes, which are among the top French scientific universities according to 2015 Shanghai ranking.

3.1. University TTOs in the French context and their patenting and licensing practices

Recent studies suggest that the organization and management practices of university licensing can significantly affect the performance of the technology transfer to industry (Benassi *et al.*, 2017; Freitas and Verspagen, 2017). It is therefore important to understand how academic licensing is organized in France. As in most other developed countries, the French university-industry technology transfer landscape has radically evolved in the last two decades, putting much more emphasis on patenting and licensing. These changes contributed to increase the occurrence of university patenting and licensing in France (yet, as suggested by Conti and Gaule (2011), licensing remains small in compare to U.S. counterparts). For instance, in the last years, the CNRS was systematically ranked among the top French patent applicants, INSERM and INRA reaching high rankings too. Similarly, French universities are intensively patenting and licensing and there are various evidences that this trend is growing (Azagra-Caro *et al.*, 2006; Carayol, 2007; Lissoni *et al.*, 2008).

These changes can, at least partially, be attributed to the law on innovation and research passed in 1999 in France. This law put great emphasis on patents. It led to the creation in all French scientific universities of technology transfer offices, nowadays called SATT in France, that are dedicated to accelerating the transformation of publicly funded French research into innovations, mostly through patenting, licensing, maturation of inventions and start-up creations⁶. It also encouraged university researchers to exploit their research findings by allowing them to create their own companies (strong provision is made to help researchers do so) and to have their inventions patented or co-patented⁷. Emphasis is also placed on the fact that French universities have to retain ownership over their patents (at least they should share it with the firms they have collaborated with). Thus, the law on innovation has mostly contributed to changing the philosophy of French university with regard to patenting. Rather than modifying the legal status of university patents, as was the case in U.S., the law has introduced a new strategic orientation, and has placed stronger emphasis on licensing and patent ownership.

French TTOs enjoy a large degree of autonomy and are supposed to be able to self-finance their activities. But, in addition, they also share a more socially oriented goal in the sense that they are also supposed to contribute to the dissemination of university based technologies and to the dynamism of the local economy. The COCON Project enabled us to learn more about the licensing process from the employees at managerial positions of two SATTs (those of the Universities of Strasbourg and Grenoble-Alpes) during the meetings and workshops took place in the framework of this project. More recently, in June 2018, we interviewed the head of the legal department of the SATT of the University of Strasbourg (SATT Conectus Alsace), who is in charge of the drafting of the license agreements. The information exchange and the interview with the SATT employees largely confirmed that licensing priority is usually given to local or national firms. Those meetings also suggest that a critical issue for French TTOs is to find educated and experienced staff and to

⁶ In the framework of “Investment for the Future” program (PIA) of ANR, which aimed at pooling the TTOs, 14 TTOs, called SATT (Technology Transfer Accelerator Offices), have been created in France in 2012. However, some universities had already structures dedicated to transferring their technologies prior to SATT. The Innovation Act of 1999 first resulted in the creation of internal TTOs called SAIC (Services for Industrial and Commercial Activities) allowing them to employ external staff and to run the organization according to more business-like budgeting/accounting rules (Della Malva *et al.*, 2013). Subsequent acts that led to SATT, mostly enabled universities to implement more autonomous strategies as regards to their technology transfer activities (Matt and Schaeffer, 2012). (For further information on SATT, see <https://www.satt.fr/>. For SATT Conectus Alsace, the TTO of University of Strasbourg, see <http://www.conectus.fr/fr> and for SATT Linksium, the TTO of University of Grenoble Alpes, see <https://www.linksium.fr/>).

⁷ In the current legislative context, French academic scientists can earn a significant share of the income derived from patenting and licensing their inventions (they can earn up to 50% of the net benefits generated by a license), which should therefore encourage them to actively participating in the transfer in order to maximize its chance of success.

keep them working for the TTO in the long term. Indeed, even if we do not have statistics about TTO staff turnover rate, it was stressed that the limitation of turnover as being an important challenge. The creation of SATT, and the important financial effort that came with it, is perceived as an important step in order to retain in house experienced staff.

The organization of the licensing process in French universities is quite similar to international and U.S. standards (see for instance the licensing cycle at Stanford University, Barlatier et al., 2017). The first step for the TTO staff is to identify valuable technologies in university labs. The inventions are identified through the invention disclosures. An important effort of communication and prospection is therefore made towards the academic community to increase the number of invention disclosures. Afterwards, the requirements of the market are identified and a patent is applied for if the invention has a commercial potential. The next step is to invest in the maturation⁸ of the invention, if needed, and then to look for a licensee. There are two options at this stage: either, with the assistance of the SATT, the inventor can create her or his own spinoff to which the technology can then be licensed; or the technology can be licensed to an already existing firm, be it a local, domestic or foreign one. When the licensee firm is identified, the last step is to negotiate the terms of the license, which can last up to one year. Our interview confirms that discussions about exclusivity are critical part of the negotiation. As to the determinants of the terms of the license, the interviewee report that they pay a lot of attention to the expected market of the licensed technology, to its properties (whether it is a technology that can be used in multiple markets, whether it is still far from the market, etc.) and to the ability of the firm to valorize the licensed technology (this last point is reported to be critical in particular when an exclusive license is granted). At the end of the licensing process, it is the president of the SATT who decides to accept or not the terms of the license negotiated between the firm and the TTO staff.

It is important to note that inventors usually do not take part in the negotiation. They have been consulted upstream but the negotiation of the license with the firm is conducted without them. That is to say, inventors are consulted regarding the technical feasibility of their inventions or to find a company, but they are not directly involved in the negotiation of licensing agreements, especially

⁸ To facilitate the licensing of inventions and creation of start-ups, Conectus (the predecessor of SATT Conectus Alsace) created the first “Maturation Fund” in France, with the contribution of local public authorities, which is used to develop very early stage inventions into proof of concepts or functional prototypes during a period of 12 to 18 months (Matt and Schaeffer, 2012). Investing in the maturation of inventions is one of the core activities carried out by its successor, SATT Conectus Alsace, in order to facilitate the research valorization process, be it licensing or spin-off creation.

when the inventor is attached to the spin-off company to which the technology may be licensed, in order to avoid any conflict of interest. A recent case study of Schaeffer et al. (2018) on university scientist from University of Strasbourg, who are highly involved in technology transfer activities, reveals that the inventors are quite effective in facilitating the marketing of technologies. Because those inventors develop enduring relations with industrialists throughout their careers, that starts mostly through informal personal links. This obviously is an important factor for finding a licensee firm.

Nevertheless, the occurrence of IP patenting and licensing is rather small in compare to most U.S. counterparts. For instance, in 2016 alone, 39 new IPs validated (patent and software), 12 new licensing contracts concluded, €1.6 million revenue obtained from IP valorization by the SATT Conectus Alsace on behalf of University of Strasbourg⁹.

3.2. Collection of the data

The data used in this paper have been collected in two stages. In the first stage, we have analyzed and coded the terms of all the licensing contracts of the two universities, i.e. 115 contracts (63 from Grenoble and 52 from Strasbourg). Since this number of licenses might appear as quite low for non-European readers it is important to mention here that i) this number is in line with other European universities¹⁰ and; ii) it represents an exhaustive picture of the two universities we are studying in the sense that we have collected all the licenses executed by these two universities during the considered period. At the second stage, we have conducted, in September 2015, an online survey sent to 226 inventors (those for whom we found one valid email address) out of the 261 inventors mentioned in the licensing contracts.

⁹ It is also interesting to note that the occurrence of diverse research valorization contracts other than licensing (e.g. research collaborations, consulting, material transfer agreements, joint PhD contracts), appear to be more frequent. To illustrate, in 2017 alone, 185 non-IP based research valorization contracts concluded and generated €4.8 million in comparison to 17 IP-based valorization contracts executed by the TTO of University of Strasbourg. (The information regarding these recent statistics has been retrieved from the internal presentations provided by the SATT Conectus Alsace and the press releases.)

¹⁰ A study by Conti and Gaule (2011) reveals that the average number of licenses concluded in 2007 was 26.4 for U.S. universities whereas it was only 7.8 for European universities (median number was 13 for U.S. and 4 for European universities). This study therefore suggests that the case of the universities of Strasbourg and Grenoble Alpes are not exceptional for European universities. Conti and Gaule (2011) relate the gap between U.S. and Europe to the differences in basic academic research and in industry experience of TTO staff in favor of U.S.

3.2.1. The codification of the terms of the contracts

The primary source of data comes from the codification of the license contracts. A license contract is a written, legal document that can be long and complex for people not expert in law. After accessing these confidential contracts, we digitized and coded them, i.e. we reduced them into a set of variables that describe and characterize them. To do this, a coding grill has been established with all the variables that are perceived as relevant for this project, such as the type of contract, names of inventors and inventions, the parties involved and their characteristics, remuneration scheme, exclusivity terms and restrictions, the existence of grant back obligations, etc. Since some information was not always explicitly mentioned in the contract, we completed the data by using various alternative sources (patent databases). This work of translation was realized with the help of lawyers who are part of the COCON project and specialized in contracts and IP law.

In order to minimize the probability of misreads, we have implemented a systematic “double coding” of the contracts, meaning that each contract has been at least partly coded by two different researchers followed by a comparison and consensus discussion. Indeed, even if the coding of some variables, such as the length or the type of contract, is usually straightforward, the coding of other variables can be trickier. For example, it is not always obvious to understand whether a license is exclusive or non-exclusive, in particular because some contracts can be based on many different inventions and some of them are exclusively licensed while others are non-exclusively licensed.

Thanks to this coding phase, for each invention mentioned in the contracts we have determined the degree of exclusivity, the type of knowledge transferred, the scientific domain, the characteristics of the licensee firm and the institutional environment.

3.2.2. Online inventor survey

The second source of data used in this work comes from an online inventor survey, where inventors were asked questions concerning certain characteristics of their inventions: maturity, specificity and appropriability. This type of information cannot easily be observed and is obviously not found in the licensing contracts. A specific expertise is needed to assess these properties of a technology. Our guess is that inventors can be a valuable source of information in order to evaluate the characteristics of the invention they have authored. We have therefore sent a questionnaire to all the inventors mentioned in our dataset, for whom we had a valid email address, asking them questions

about the characteristics of their invention (for a detailed description of the terms used in the questionnaire see the Table A1 in Appendix). Out of 115 contracts, we have been able to find at least one contact address for 94 contracts and out of these 94 contracts we received at least one answer for 62 contracts. Overall, this corresponds to 91 inventions¹¹ (Table 1).

Table 1. Number of contracts, inventors and inventions

Number of license and cession contracts (<i>patent, knowhow and software license and cession contracts</i>)	62
Number of inventors (<i>respondents</i>)	83
Number of inventions (<i>unit of analysis</i>)	91

3.2.3. Consistency check

As shown in Table 1, the number of licensing contracts is not equal to the number of inventions and to the number of inventors because in some cases we have more than one invention in a licensing contract and in some cases we have more than one inventor engaged in an invention (similarly, a single inventor can be mentioned in different inventions). This means that sometimes, for the same invention, we have responses from different inventors. This was the case for 22 inventions. This enables us to compare the responses of these different inventors and to perform a consistency check in order to verify whether the perception of different inventors as to the characteristics of the same invention is the same. This is important given the complexity of the questions and the fact that some questions in the survey might have been misunderstood by the respondents.

In order to evaluate the consistency of the respondents' answers, we resort to a simple rule. We attribute a value between 0 and 1 for each response. For instance, regarding the embryonic nature of the technology, the inventor can choose among the answers "embryonic", "moderately embryonic" and "mature". We therefore attribute the value 1 to "embryonic", 0.5 to "moderately embryonic" and 0 to "mature" and we consider that the answers provided by the respondents are incoherent when two different respondents gave two different extreme answers, that is to say when the difference between two answers equals to 1 (e.g. one of the inventors considered the invention as

¹¹ We have been able to detect 241 inventions contained in 108 contracts out of 115 contracts. This is because for a couple of contracts, the bulk of inventions may go up to 20 inventions or even more. For the remaining 7 contracts, we couldn't find the invention counts because the relevant parts in digitized versions were missing (i.e. the annexes where the inventions were mentioned for some contracts). It was also difficult for some contracts to determine whether the licensed inventions are a single invention or if certain components should be considered as separate inventions (for instance the source code of a software), which requires further technical and legal expertise.

mature while another considered as embryonic). We take the ratio of coherent responses in order to check the robustness of the answers. This leads to the following results: for the embryonic versus mature dimension, we have 100% consistent answers; 82% for the specific versus generic one; and 91% for the appropriability one (Table 2). Given the relative high value of these convergence rates of answers we consider that the respondents have correctly understood the questions with regard to the characteristics of the technology.

Table 2. Inventors' survey: consistency check

Value	MATURITY	SPECIFICITY	APPROPRIABILITY
1	Embryonic	Generic	Strong appropriability
0.5	Moderately embryonic	Moderately generic	Relatively strong appropriability
0	Mature	Specific	Weak appropriability
<i>Consistency rate</i>	100%	82%	91%

Then, in order to determine which value to attribute to the invention when we have multiple responses, we compute the average value of the answers given by the different respondents. If this average value is equal to or above 0.5, we attribute a value of 1, and if it is below 0.5, we attribute the value 0. To illustrate, again let us take the case of the technological dimension embryonic versus mature and let us assume three respondents, two of whom consider the invention is embryonic and one that it is mature, thus leading to an average answer of 0.66. This average value being above 0.5 we consider that the technology is embryonic.

3.3. Econometric treatment

In this part, we use the data to explore the propositions set forth in section 2. To ascertain the extent to which the invention characteristics moderate the degree of exclusivity of a licensing contract, we resort to different dependent variables (Table 3). As a first approach we study the probability that the invention has been exclusively licensed (model 1) as a function of the invention's properties and some control variables. To do so we rely on the variable *Global_excl* which takes the value 1 if the invention has been granted a global exclusivity and 0 otherwise. Since the dependent variable is a dummy, we rely on a logit model.

As a second approach, we detail a little bit more the dependent variable (model 2). We consider the dependent variable *Order_excl* which takes the value 0 if the invention has been non-exclusively licensed, 1 if it has been licensed exclusively per field of use and 2 if it has been subject to a global exclusive license. This second model is estimated with an ordered logit regression since we consider that an exclusive license per field of use is an intermediate level of exclusivity in between a non-exclusive and a global exclusive license.

Finally, as a third approach, we study the probability that the invention has been exclusively licensed per field of use (model 3). We thus consider the dependent variable *Exclu_pfu*, which takes the value 1 if the invention has been exclusively licensed per field of use, and 0 otherwise. We estimate this model with a simple logit regression.

Table 3. Description of dependent variables

Model	Variable	Definition	N	Mean	Std. Dev.	Min	Max
Model 1	<i>Global_excl</i>	Binary variable indicating whether the invention is granted a global exclusivity (unrestricted exclusivity/no field of use restriction)	91	0.28	0.45	0	1
Model 2	<i>Order_excl</i>	Variable ranked between 0-2. It takes value 0 if the invention is non-exclusively licensed, 1 if it is licensed exclusively per field of use and 2 if it is subject to a global exclusive license	91	1.10	0.68	0	2
Model 3	<i>Exclu_pfu</i>	Binary variable indicating whether the invention is granted an exclusive license per field of use (restricted exclusivity)	91	0.53	0.50	0	1

Note: Dependent variables are obtained through the COCON contract codification

3.4. Variable specification

3.4.1. Main explanatory variables

Our main explanatory variables deal with the properties of the invention. The data on the invention characteristics come from the inventor survey. We take into account three technological properties (Table 4). *Embryonic* is a binary variable indicating whether the invention is embryonic or not. It takes the value of 1 if the invention is embryonic, and 0 otherwise. *Generic* is a binary variable indicating whether the invention is generic or specific. It takes the value 1 if the invention is generic, 0 otherwise. *Appro* is a binary variable indicating whether the invention is appropriable (indicating therefore that the technology is difficult and costly to imitate even without legal

exclusivity). It takes the value 1 if the invention is considered as appropriable, 0 otherwise. Furthermore, *Emgen* is a binary variable which indicates whether the invention is both embryonic and generic. It takes the value 1 when the invention is both embryonic and generic, 0 otherwise.

3.4.2. Control variables

As to the *Controls*, we include different variables that may have an effect on the licensing strategy. First, we control for several characteristics at the technological level. In order to capture the effect of the scientific domain we include dummy variables for two scientific disciplines that are known as specific as regard to licensing: life sciences & chemistry on the one hand and software on the other hand¹². Then, we control for the kind of knowledge that is transferred. We include a dummy variable to control for contracts that also transfer tacit knowledge to some extent. It is indeed more difficult to transfer tacit knowledge as compared to codified one. It requires face-to-face interactions (Kim and Vonortas, 2006), which increase the cost of transfer with the number of licensees (Aulakh *et al.*, 2010). Therefore, in order to minimize the cost of the transfer, non-exclusive licenses might be less often in the presence of tacit knowledge.

Second, we control for the various characteristics of the licensee firm. To capture the effect of firm size, we include a dummy *Micro* taking the value 1 when the licensee is a micro enterprise. For this variable we adopt the INSEE¹³ definition and collect the data from AMADEUS database. We also include a dummy *Spinoff* in order to capture whether the licensee firm was an academic spin-off of the university¹⁴. This data comes from contract codification. Entrepreneurial firms such as small academic spin-offs or start-ups usually seek for strong IP protection and hence exclusive licenses (Shane, 2002). However, on the other hand, these small firms also lack the ability to exploit the technology, as compared to incumbent firms, thus making TTOs more reluctant to deliver exclusive

¹² Colyvas *et al.* (2002) show that scientific domain has an impact on the exclusivity of a contract and stress the specificity of life sciences. Anand and Khanna (2000) find that more than a half of the transfers in chemicals involve some exclusivity clause, 40 % of whom involve a global (or worldwide) exclusivity whereas exclusive contracts are less common in computers (18%). Lemley (2008) also emphasizes the differences in scientific disciplines in relation with the exclusivity of licensing. Similarly, Bessen and Maskin (2009) and Maurer and Scotchmer (2006) stress the specificity of software as regard to licensing.

¹³ INSEE (National Institute of Statistics and Economic Studies in France) defines micro-enterprise as a business with fewer than 10 employees and with an annual or total balance sheet not exceeding 2 million Euros. (Accessed on <https://www.insee.fr/en/metadonnees/definition/c1079>). The other INSEE categories are small and medium-sized enterprises (SMEs), intermediate-sized enterprises (ISEs) and large enterprises.

¹⁴ Note that the two variables *Spinoff* and *Micro* might not necessarily be strongly correlated. When it is created, a spin-off is usually a micro firm but this might not be the case in our database. Indeed, at the time of the study, some spin-offs might have developed and become SMEs. This is the case for a significant number of spinoffs that are not micro firms in our database. Similarly, some micro firms might not be spinoffs of the universities of Strasbourg or Grenoble.

license. In addition, we also control for the country where licensee firm is located. *France* is a binary variable taking the value of 1 if the licensee firm is located in France, and 0 otherwise. In a study on the licensing contracts in U.S., Anand and Khanna (2000) find that probability of exclusive license is slightly higher when the licensee is located within the same country to the licensor. In a similar vein, for the university licensing context, we expect more exclusive licensing deals with firms located in France in compare to those that are not. This might be so because TTOs may want to develop local and national business but also because they may find it easier to monitor an exclusive deal within the same country. IPR system significantly differs from one country to another (Bessy *et al.*, 2010) and exclusive licenses are risky as the dissemination of the technology may result in shelving (Dechenaux *et al.*, 2009) due to weak monitoring by the TTO. Licensor could be reluctant to bare the potential risk of licensee non-performance at a global scale, especially in the case of global (or worldwide) exclusive licenses (Somaya *et al.*, 2011). Monitoring of the exclusive licensee could thus be easier if the licensee is within the same country.

Third, we control for the institutional environment. In order to capture the effect of different managerial approaches while transferring the university technology, we control for the type of university. *Unistra* is a dichotomous variable taking the value of 1 if the licensor is University of Strasbourg; and 0 if the licensor is University of Grenoble Alpes. We also try to control for the possible role of other public research organizations such as CNRS or INSERM. *Involve_PRO* is a dichotomous variable taking the value of 1 if at least one French public research organization such as CNRS, CEA, INRA was involved in the licensing of a technology along with the university.

3.5. Descriptive statistics

Tables 3, 5 and 6 provide an overview of the data and some descriptive statistics. The vast majority of the 91 inventions was exclusively licensed and mostly restricted (Table 3). 28% of the inventions were granted global exclusivity¹⁵; 53% exclusivity per field of use (restricted exclusivity) and only 19% a non-exclusive license¹⁶. Regarding the invention characteristics, 63% of the inventions are

¹⁵ Among the licenses that have been subject to global exclusivity we have included 8 cession contracts (corresponding to 9 inventions), i.e. contracts which sell the invention to the industrial partner. We consider that, given the objective of our research, it is similar to grant global exclusivity in a license or to sell the invention. In both cases the licensee obtains the exclusive right over the exploitation of the invention.

¹⁶ These figures are in line with what we find in the initial sample of 241 inventions (before we reduce it in order to do the matching with the online inventor survey). Indeed, out of 241 inventions in our initial sample, 19.1 % are granted a global exclusivity, 59.3% are an exclusive per field of use license and 21.6 % are a non-exclusive license.

considered as embryonic, 66% as generic, 40% as both embryonic and generic and 70% as appropriable (and hence difficult to imitate even without legal exclusivity)¹⁷.

Concerning the control variables, 35% of licenses include a transfer of tacit knowledge; 54% of all inventions licensed are either in life sciences or in chemistry, and 23% are in software¹⁸. As to the licensee firm characteristics, 65% are micro enterprises, 49% of licensees are academic spin-offs and 82% are located in France. Finally in 42% of licensing contracts, we also observe the involvement of non-university French public research organization (PRO) such as CNRS or INSERM, etc. Respective correlation coefficients reported in Table A2 in Appendix.

Table 4. Description of explanatory and control variables

Variable	Definition	Source
Main independent variables		
<i>Embryonic</i>	Binary variable indicating whether the invention is embryonic (either embryonic or moderately embryonic)	COCON inventor survey
<i>Generic</i>	Binary variable indicating whether the invention is generic (either generic or moderately generic)	COCON inventor survey
<i>Emgen</i>	Binary variable indicating whether the invention is both <i>Embryonic</i> and <i>Generic</i>	COCON inventor survey
<i>Appro</i>	Binary variable indicating whether the invention is difficult and costly to imitate (either strong or relatively strong appropriability)	COCON inventor survey
Control Variables:		
<i>Tacit</i>	Binary variable indicating whether the contract includes tacit knowledge (e.g. technical assistance, consultancy services, training of staff etc.) (Definition of Bessy <i>et al.</i> , 2010 is adopted)	COCON contract codification
<i>Life Sci_or_Chem</i>	Binary variable indicating whether the invention belongs to either the scientific domains of life sciences and/or chemistry	IPC (if patent)and COCON contract codification (if know how)
<i>Software</i>	Binary variable indicating whether the invention belongs to the scientific domain of software	COCON contract codification(we created a new class "T" which is not in IPC)
<i>Micro</i>	Binary variable indicating whether the size of licensee firm is micro	AMADEUS database (INSEE definition: less than 10 employees and a turnover or total annual balance sheet not exceeding 2 million EURO)

¹⁷ Frequencies are calculated after the exclusion of "don't know" responses from the respective samples. This explains why the number of observations is less than 91.

¹⁸ Note that one invention can belong to several disciplines.

<i>Spinoff</i>	Binary variable indicating whether the licensee firm is an academic spin-off	COCON contract codification
<i>France</i>	Binary variable indicating whether the licensee firm is located in France	COCON contract codification
<i>Unistra</i>	Binary variable indicating whether the licensor is University of Strasbourg	COCON contract codification
<i>Involve_PRO</i>	Binary variable indicating whether there is involvement of a non-university PRO in the licensing process	COCON contract codification

Table 5. Descriptive statistics of explanatory variables

Variable	N	Mean	Std. Dev.	Min	Max
Embryonic	82	0.63	0.48	0	1
Generic	82	0.66	0.48	0	1
Emgen	82	0.40	0.49	0	1
Appro	83	0.70	0.46	0	1
Tacit	91	0.35	0.48	0	1
Life_Sci_or_Chem	91	0.54	0.50	0	1
Software	91	0.23	0.42	0	1
Micro	91	0.65	0.48	0	1
Spinoff	91	0.49	0.50	0	1
France	91	0.82	0.38	0	1
Involve_PRO	91	0.42	0.50	0	1
Unistra	91	0.40	0.49	0	1

Table 6. Cross tabulation: degree of exclusivity and invention characteristics

Exclusivity	Maturity			Specificity			Appropriability		
	<i>Mature</i>	<i>Embryonic</i>	<i>Total</i>	<i>Specific</i>	<i>Generic</i>	<i>Total</i>	<i>Weak</i>	<i>Strong</i>	<i>Total</i>
Non exclusive	9	6	15	5	10	15	4	12	16
Exclusive per field of use	16	32	48	16	32	48	11	37	48
Global exclusive	5	14	19	7	12	19	10	9	19
Total	30	52	82	28	54	82	25	58	83

Table 6 cross tabulates the exclusive (global and per field of use) versus non-exclusive dimension of the license with the characteristics of the technology. This gives a first indication about the links between the nature of the license and the properties of the technology. For instance, we can see that mature inventions are more often granted non-exclusive licenses (9 inventions) than global exclusivity (5 inventions). On the other hand, embryonic inventions are more subject to global exclusivity. Similarly, if we look at generic inventions we see that they are more often subject to global exclusivity (12 inventions) than non-exclusive licenses (10 inventions) which runs against our theoretical predictions. Finally, if we look at inventions which are appropriable we see that they are more likely to be non-exclusively licensed which is in line with theoretical predictions (non-appropriable inventions are also more likely to be licensed with global exclusivity).

4. Econometric results

The results of the estimations are reported in Table 7, Table 8 and Table 9. In order to test the robustness of our results, we used different specifications in each three model by adding or removing some variables. In Table 7 and Table 8, columns (1), (2), and (3) show the single effects and column (4) shows the overall effect of the main interest variables on exclusivity. Then we stepwisely introduce control variables. In column (5), we add only the controls regarding technology-level characteristics. In column (6), we add only the firm-level characteristics and in column (7), we add only the institutional-level characteristics. Finally in column (8), we regress on the complete set of variables.

Our results provide a weak support only for the proposition suggesting that the more appropriable the technology the less likely it is exclusively licensed. This effect is important only in the case of a global exclusivity (model 1) as it is robust to different specifications of the model. However, it disappears when one also considers the other degrees of exclusivities (model 2 and model 3). Moreover, we cannot find a significant relation between the degree of exclusivity and the other characteristics of the technology. In particular, we do not observe that the more embryonic or the more specific the technology the more exclusive the license is. To illustrate, in the case of specificity, the coefficient is not significantly negative. This means that generic technologies are not linked to more non-exclusive licenses, which could possibly reduce the exploitation of possible applications and their effective diffusion. Overall, with the exception for the appropriability

dimension, our results do not allow us to conclude that the perceived nature of the technology significantly affect the exclusive versus non-exclusive nature of the license.

As for the control variables, we find that the size of the licensee firm matters. Micro enterprises are significantly more likely to be granted exclusive and even global exclusive license. This is compatible with the literature claiming that firms lacking complementary assets and competitive advantage need more exclusivity to catch-up with their incumbent counterparts (Shane, 2002). Yet, micro companies gaining exclusive licenses could also reflect that technologies with little potential are licensed to these firms in an exclusive basis instead of letting those technologies remain on shelves. Surprisingly, academic spin-offs do not get more exclusive license as the coefficient is negative and significant. Although spin-offs are also in need of support through exclusive licenses to catch-up with existing companies, this absence of exclusive deals could be related to TTOs' will to maximize the probability of exploitation of the licensed technology, thus leading them to avoid granting an exclusive right to spinoffs. Even if also small in size, in the case of established micro companies, non-exploitation risk could be lower in comparison to spin-off firms. However this proposition requires further investigation. Furthermore, the significant results concerning the firm-level characteristics (as well as appropriability) might also be pointing towards the effect of the licensee on the exclusivity decision and its bargaining power.

Concerning the effect of scientific domain, software inventions do not significantly reduce the probability of exclusive license. Regarding the domain of life sciences and chemistry, we cannot link the inventions in this domain to global exclusive licenses since the coefficient is negative and significant. Interestingly, the involvement of PROs in the licensing agreement has a negative effect on the granting of global exclusive licenses (model 1), but a positive one on the granting of exclusive licenses per field of use (model 3). One explanation might be that the involvement of multiple public institutions is associated with a more important public support and investment. Thus, in this case, TTOs may choose to limit global exclusivity and to envisage more sophisticated licensing deals, such as licenses per field of use, which they might consider more beneficial to public interest.

Table 7. Results of logit regression for model 1

Dependent variable	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>Technology level:</u>								
Embryonic	0.611 (0.581)			0.425 (0.605)	0.503 (0.674)	-0.398 (0.755)	0.515 (0.675)	-0.856 (1.056)
Generic		-0.154 (0.546)		-0.075 (0.572)	-0.074 (0.651)	0.159 (0.661)	0.382 (0.707)	0.559 (1.126)
Appro			-1.289** (0.546)	-1.297** (0.557)	-1.646** (0.644)	-1.116* (0.655)	-1.708** (0.678)	-2.841** (1.206)
Tacit					-0.342 (0.802)			1.237 (1.515)
Life_Sci_or_Chem					-1.589** (0.736)			-3.533** (1.548)
Software					0.470 (0.807)			-1.568 (1.721)
<u>Firm level:</u>								
Micro						3.201*** (1.156)		5.548** (2.291)
Spinoff						-1.158* (0.679)		-0.520 (1.081)
French						0.456 (1.006)		-0.728 (1.563)
<u>Institutional level:</u>								
Involve_PRO							-2.687*** (0.879)	-3.414** (1.382)
Unistra							-0.260 (0.697)	-1.633 (1.204)
Constant	-1.609*** (0.490)	-1.099** (0.436)	-0.405 (0.408)	-0.612 (0.730)	0.315 (0.876)	-2.694* (1.506)	0.198 (0.861)	0.507 (2.053)
Observations	82	82	83	82	82	82	82	82
LR chi2	1.17	0.08	5.59	6.65	16.95	21.95	22.66	46.36
Prob>chi2	0.2803	0.7783	0.0181	0.0839	0.0095	0.0012	0.0004	0.0000
Pseudo R2	0.0131	0.0009	0.0626	0.0749	0.1909	0.2473	0.2552	0.5222
Log likelihood	-43.8064	-44.3495	-41.8568	-41.0635	-35.9157	-33.4139	-33.0600	-21.2071

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 8. Results of ordered logit regression for model 2

Dependent Variable	Order_excl	Order_excl	Order_excl	Order_excl	Order_excl	Order_excl	Order_excl	Order_excl
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>Technology level:</u>								
Embryonic	0.911* (0.471)			0.739 (0.480)	0.748 (0.482)	0.211 (0.538)	0.765 (0.481)	0.137 (0.550)
Generic		-0.107 (0.457)		-0.088 (0.460)	-0.288 (0.493)	0.049 (0.499)	-0.019 (0.467)	-0.169 (0.535)
Appro			-0.951* (0.490)	-0.991* (0.511)	-1.070** (0.521)	-0.683 (0.537)	-1.010** (0.509)	-0.797 (0.558)
Tacit					0.397 (0.517)			0.681 (0.611)
Life_Sci_or_Chem					-1.099* (0.565)			-1.082* (0.605)
Software					-0.464 (0.806)			-0.875 (0.872)
<u>Firm level:</u>								
Micro						2.201*** (0.630)		2.357*** (0.654)
Spinoff						-1.265** (0.528)		-0.973* (0.563)
French						0.978 (0.707)		0.584 (0.778)
<u>Institutional level:</u>								
Involve_PRO							-0.617 (0.472)	-0.527 (0.518)
Unistra							-0.166 (0.471)	0.045 (0.526)
Constant cut1	-0.968 (0.384)	-1.568 (0.420)	-2.169 (0.483)	-1.910 (0.679)	-2.783 (0.838)	-0.762 (0.852)	-2.294 (0.728)	-2.014 (1.158)
Constant cut2	1.839 (0.436)	1.129 (0.396)	0.580 (0.409)	1.005 (0.656)	0.246 (0.772)	2.824 (0.941)	0.685 (0.689)	1.709 (1.172)
Observations	82	82	83	82	82	82	82	82
LR chi2	3.86	0.05	3.86	7.76	11.87	27.18	10.15	31.70
Prob>chi2	0.0493	0.8148	0.0495	0.0513	0.0649	0.0001	0.0710	0.0009
Pseudo R2	0.0245	0.0003	0.0239	0.0491	0.0752	0.1721	0.0643	0.2007
Log likelihood	-77.0362	-78.9408	-78.7118	-75.0890	-73.0327	-65.3765	-73.8918	-63.1206

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 9. Results of logit regression for model 3

Dependent variable	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<u>Technology level:</u>									
Embryonic	0.336 (0.464)				-0.481 (0.859)	-0.695 (1.020)	-0.324 (0.932)	-0.097 (1.018)	-0.266 (1.209)
Generic		0.087 (0.472)			-0.839 (0.844)	-1.769* (1.037)	-1.063 (0.892)	-0.767 (0.974)	-1.761 (1.084)
Appro			0.808* (0.487)		0.836 (0.511)	1.278** (0.624)	0.969* (0.547)	1.094* (0.609)	1.697** (0.739)
Emgen				0.571 (0.467)	1.419 (1.037)	2.428* (1.267)	1.509 (1.092)	1.062 (1.209)	2.303 (1.489)
Tacit						1.311* (0.676)			1.120 (0.850)
Life_Sci_or_Chem						1.009 (0.618)			1.321* (0.740)
Software						-1.861** (0.945)			-1.474 (1.138)
<u>Firm level:</u>									
Micro							-0.446 (0.573)		-0.185 (0.766)
Spinoff							-0.075 (0.560)		-0.351 (0.724)
French							0.812 (0.729)		1.636 (1.098)
<u>Institutional level:</u>									
Involve_PRO								2.325*** (0.604)	2.291*** (0.694)
Unistra								0.047 (0.591)	-0.005 (0.695)
Constant	0.134 (0.366)	0.288 (0.382)	-0.241 (0.403)	0.123 (0.286)	0.060 (0.812)	-0.554 (0.982)	-0.373 (0.940)	-1.232 (1.027)	-3.194** (1.521)
Observations	82	82	83	82	82	82	82	82	82
LR chi2	0.53	0.03	2.79	1.52	5.17	24.01	6.93	25.48	40.02
Prob>chi2	0.4684	0.8538	0.0950	0.2177	0.2705	0.0011	0.4362	0.0003	0.0001
Pseudo R2	0.0047	0.0003	0.0247	0.0137	0.0464	0.2157	0.0623	0.2290	0.3596
Log likelihood	-55.3742	-55.6201	-55.1150	-54.8773	-53.0529	-43.6343	-52.1718	-42.8955	-35.6284

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The results of model 3 are presented in Table 9. We follow the same model specifications used in Table 7 and Table 8, in which we introduce technology, firm and institutional-level controls in turn. Here, we particularly aim to explore the proposition claiming that inventions that are characterized

both embryonic and generic should be linked to exclusive license per field of use. In order to see this effect, we have introduced in the regression the variable *Emgen*. Again, our results do not support the proposition. Although, the sign of the variable *Emgen* is positive and significant in column (6), it is not robust to other specifications of the model.

5. Discussion and conclusion

In this paper, we have investigated the role played by the characteristics of the technology in shaping the way it is licensed by universities. In particular, we have examined whether the different properties of the licensed technology (i.e. distance to market, degree of specificity, degree of appropriability) affect the probability of technology having licensed exclusively or non-exclusively. Our prediction was that the properties of the technology should enter into account when defining the terms of the license, since different technological properties may lead to different economic performance of a license. In order to test the relationship between the properties of the licensed technology and the exclusive nature of the license, we relied on a unique and original dataset of 91 inventions contained in 62 intellectual property licensing (and cession) contracts executed by two leading French universities.

Our results are obviously exploratory and must be interpreted with care, since they are based on a limited number of observations. However, they indicate that characteristics of the technology do not seem to have a significant effect on the nature of the license. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. Similarly, inventions which are both generic and embryonic are not significantly linked to exclusive licenses per field of use. Finally, and in line with our theoretical predictions, the more appropriable the technology, the less likely it is to be globally exclusively licensed. However, this relation does not hold for the exclusive per field of use licenses.

Two important contributions of this study are particularly worth emphasizing. First, we have obtained unique and very detailed information on the characteristics of the university licenses and the properties of the licensed technologies (via our inventor survey). This unique and original dataset (obviously limited in size given the workload required to collect the information) has enabled us to explore, for the first time, the link between the nature of the license and some

properties of the technology. As a second contribution, we have been able to show that, as opposed to most of the theoretical predictions, the properties of the technology do not seem to significantly affect the degree of exclusivity of the license.

Our research has several implications for practitioners and policy makers. First and foremost, our study reveals some possible source of inefficiency. It indeed suggests that university licensing might not always be in line with the interest of the public, i.e. might not maximize social welfare. For instance, many technologies in our sample have been considered as mature and still were exclusively licensed. Similarly, many technologies have been considered as generic, with multiple applications in different domains, and still they were granted a global exclusivity. Why is this so? Why are university technology licensing practices not taking more into account the characteristics of the licensed technology in order to develop welfare enhancing technology deals whereas, at least in France, universities are almost exclusively publicly funded? We see two possible explanations.

First, TTO staff might lack adequate technical skills and competences which could prevent them from designing optimal licensing contracts. By optimal, we mean designing a contract with an appropriate exclusivity scheme considering more the various characteristics of the technology, which then allows the effective diffusion with a least cost to the society. But they might not always be in the position to assess correctly these properties, which indeed require specific skills and competences difficult and costly to acquire. This suggests that there might be room for significant improvements in the management and organization of university technology transfer in order to increase its performance. One possibility for TTO staff could be to involve more the inventors in the licensing process since they have unique and valuable information concerning the characteristics of the technology. This type of information could be obtained at initial stages, for instance through more detailed invention disclosure forms containing questions regarding the inventors' perception about the invention (i.e. stage of development, specificity, appropriability, complexity etc.) which could later be verified by independent technology experts. This pre-marketing knowledge regarding the nature of the technology might help university TTOs to reduce uncertainties related to the technology, to find a suitable licensee that can better exploit the technology, to design optimal contracts with an appropriate exclusivity scheme and to obtain a strong bargaining position. To our knowledge, in most French TTOs, inventors are involved in the drafting of the patent but rarely in the drafting of the licensing contract. As revealed in Schaeffer et al. (2018), inventors that are highly active in technology transfer activities are also very effective in helping the marketing of the

technologies since they develop informal and enduring relations with the industrial employees and build mixed teams consist of academic and industrial researchers. Therefore experienced inventors can go beyond providing only their technical expertise. Their awareness of industrial needs combined with their technical knowledge may suggest that they could be a valuable resource while designing an optimal contract balancing the needs of industry and university. However, whether their involvement at the negotiation stage helps to improve the licensing process should be verified by examining such practices.

Second, TTOs might lack bargaining power in order to negotiate optimal licensing contracts with firms. The content of a license is indeed the outcome of a bargaining between a university and its TTO and a licensee firm. Therefore, even though the TTO aim at maximizing social welfare, it might lack the bargaining power in order to do so. Firms usually prefer exclusive terms and they will not hesitate to bargain hard in order to get one. It is therefore possible that universities and TTOs, which have important financial constraints, sometimes accept to grant an exclusive license even though they are aware that it is not the ideal solution. They might prefer to grant a license that is not entirely in the interest of its public mission rather than not granting a license at all. This might especially be prominent in systems where the licensing activity is low which puts further pressures for the TTOs. From a policy perspective this means that it might be inefficient to impose tight financial constraints to TTOs. This might encourage them to accept licensing deals that are financially interesting even though detrimental from a social welfare point of view. Instead of the performance metrics based on the number of licensing contracts executed or the revenues generated out of these contracts, the metrics based on the social impact of licensing practices could be developed. The latter might incentivize TTOs to conclude socially beneficial licensing deals.

We believe that the insights put forward in this research open many doors and suggest some promising lines of future research. First of all, this discussion at least calls for a deeper investigation on the primary objective of universities and their TTOs when valorizing their technologies and on how the different objectives are prioritized. What should be the objective of the valorization of university research? Should it be to provide universities with new financial resources? Or should it be to make sure that an invention generates economic wealth? In the second case, what is the best way to transfer the technology? Via a non-exclusive license? Via the creation of a start-up endowed with an exclusive license? Or others? According to the answers to these questions, the design of the license will be largely different. Moreover, it would be an interesting, yet a rather difficult, research

venue to investigate whether our propositions on the appropriate licensing strategy corresponds to the practices. For instance, whether in the context for which we suggest a non-exclusive licensing may yield a better societal (as well as economic) benefit than the instances where an exclusive license was granted instead and vice versa. A comparative case study could be considered to examine such practices. Investing in the maturation of early stage inventions is one of the core activities of French TTOs, which could be helpful to reduce uncertainty regarding the technology and asymmetric information between the licensor and the licensee. Thus, it could also be interesting to investigate how such practices affect the bargaining power of the university and the exclusivity decision. One of the limitations of our research is that, we focused only the supply side than the demand side of the licensing process. However, the significant results concerning the firm-level characteristics (as well as the appropriability) might be pointing towards the effect of the licensee on the exclusivity decision and hence its bargaining power. Thus, future research should examine more the demand side by considering for instance the variables such as market size or competition regime.

An obvious limitation of our research is the small sample size. Despite the originality and the richness of information in our dataset, the small number of observations limits the generalizability of the results. This study should therefore be considered more like an exploratory research that aims at opening doors to future investigations. In particular, future research might perform a larger scale analysis and include more universities in more countries in order to have more observations and more generalizable results. We realize the difficulty of the task, especially in terms of data collection. Yet, these efforts are necessary in order to obtain a more robust answer to our research question. Furthermore, it might also be interesting to compare university-industry licensing with inter-firms licensing. Some studies focused on inter-firm licensing indeed suggest that the properties of the technology (in particular its embryonic nature) do affect the license (Anand and Khana, 2000; Somaya et al., 2011). Why is it different for university licensing? One way to investigate this point could be to look at the licensing of inventions co-patented between universities and firms and to observe the exclusivity scheme under this different ownership structure. Last, it is important to remind that universities and TTOs are complex organizations that face multiple and sometimes non-aligned objectives. This complexity needs also to be taken into account in the analysis.

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Appendix

Table A1. Inventors' survey

Invention characteristics	Definition
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MATURITY

Embryonic

Completely embryonic (very distant from the market): Industrialist still had to invest heavily and the time before the development was very important.

Moderately embryonic

Not fully operational: Industrialist had to invest a certain time was necessary before developing it.

Mature

Close to the market: Industrialist was able to develop as it was and without incurring any additional investment (or otherwise marginal).

I don't know

SPECIFICITY

Generic

Highly generic: It can be used in a very large number of contexts.

Moderately generic

Moderately generic: It can be used in a small number (greater than one) of different contexts and sectors.

Specific

Highly specific (targeted): It can only be used in one very specific context.

I don't know

APPROPRIABILITY

Appropriable

Very difficult to imitate: It is very long and very costly for industrial competitors of licensee to imitate the invention if it is not protected by an intellectual property right (IPR).

Relatively appropriable

Relatively difficult to imitate: It is relatively expensive and takes long time for competitors to imitate licensed technology even if it is not protected by an IPR.

Non-appropriable

Easily imitable: If it is not protected by IPR it can be reproduced by industrial competitors of the licensee very quickly and at very low cost.

I don't know

Table A2. Pairwise correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1.Global_excl	1.00													
2.Exclu_pfu	-0.67	1.00												
3.Embryonic	0.12	0.08	1.00											
4.Generic	-0.03	0.02	-0.07	1.00										
5.Emgen	0.02	0.14	0.62	0.59	1.00									
6.Appro	-0.27	0.18	-0.15	0.05	-0.07	1.00								
7.Tacit	0.04	0.10	-0.01	0.24	0.13	0.13	1.00							
8. Life_Sci_or_Chem	-0.39	0.40	-0.06	-0.07	-0.14	-0.01	0.08	1.00						
9.Software	0.35	-0.42	0.10	0.01	0.08	0.07	0.20	-0.59	1.00					
10.Micro	0.41	-0.14	0.43	-0.05	0.20	-0.20	-0.04	-0.17	0.29	1.00				
11.Spinoff	0.06	-0.03	0.18	0.19	0.31	0.01	0.05	-0.14	0.24	0.27	1.00			
12.France	0.16	0.03	0.03	0.26	0.13	-0.19	0.10	-0.14	-0.02	0.20	0.46	1.00		
13.Involve_PRO	-0.44	0.53	-0.01	0.05	0.09	0.02	0.12	0.29	-0.31	-0.12	0.05	-0.02	1.00	
14.Unistra	-0.21	0.23	-0.09	0.12	0.08	-0.06	0.16	0.21	-0.23	-0.20	-0.13	-0.16	0.36	1.00

Correlation coefficients in bold are significant at a 5% level