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University Based Open Source Technology Transfer in the Case of Sequential Inventions

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-Preliminary version-

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This paper proposes a framework to analyze the university open source technology transfer beyond software through formal patent-based licensing contracts. A licensing strategy may be based upon varying degrees of exclusivity, from exclusive license to open source license. By focusing on the case of sequential inventions as a determinant of university licensing strategy, we compare the traditional and the open source transfer mechanisms, where for the former we consider only the case of exclusive licensing and for the latter open source licensing with a "viral" clause. We also discuss the co-existence of patents with "open source innovations" where patents used as specific tools. Through the analogy with the copyrights used in free open source software, we emphasize the exceptional role of patents in ensuring the freedom of the system. Our research suggests that transferring a university-based first-generation sequential invention through patent-backed open source licensing with a viral clause may ensure the development of second-generation innovations by promoting the freedom of access at both upstream and downstream levels.

Keywords: University licensing strategies, intellectual property rights, open source transfer, sequential innovation

[1] Paper in progress, please do not cite.

1. Introduction

The stunning success of open source movement in software industry provides an alternative way of innovation organization which suggests a distributed and open model for innovation that compete with traditional proprietary and closed models (Lakhani and Panetta, 2007). Further, the success of open source model in various software projects such as GNU/Linux operating system , Apache web server , Perl has raised the issue of expanding the phenomenon beyond software (Lerner and Tirole, 2004; Pénin, 2011). Exporting the model to industries as diverse as biotechnology, pharmaceuticals, nanotechnology, online encyclopedias such as Wikipedia, geographic information systems have become a tempting research area (Maurer, 2003; Maurer and Scotchmer, 2006; Lakhani and Panetta, 2007; Pénin and Wack 2008; Lounsbury et al., 2009; Sugumaran, 2012).

Against the common belief, an important factor behind the openness and the freedom of an innovation system, which may be called "open source innovation (OSI)" (Pénin,2009;2011), could be the specific use of patents (Pénin and Wack, 2008) corresponding to "the third face of IPR" (David, 2006). A careful examination of the success behind the free open source software (FOSS) movement shows how the copyrights -"the third face of IPR"- are used as legal devices for sustaining the freedom of software when it is coupled with specific "copyleft" licenses. For the open source innovations beyond software, where copyrights cannot be used to protect the research outcomes, patents can be used to prevent appropriation of further developments as suggested for the cases of upstream research tools in biotechnology (Pénin and Wack, 2008) and open source drug discovery project for developing country diseases such as malaria and tuberculosis (Sugumaran, 2012).

Given the fact that universities being essential sources of research and technology, the issue of applicability of open source model beyond software in academic setting, especially when it comes to transferring its technology to industry, is worth investigating. However, the degree of applicability and the success of an open source technology transfer model beyond software may be closely related to the heterogeneous characteristics or the nature of the technology as well as various other determinants such as technological regime that a particular technology operates in, competition regime (Pénin, 2010), the firm specific characteristics, institutional and organizational settings. In this paper, among many other characteristics, we focus on the case of sequential inventions developed in an academic setting and compare the open versus traditional licensing strategies that may be adopted in transferring these technologies to firms. From the social welfare point of view, this inquiry requires consideration because in comparison to a static setting, in a dynamic setting, where the innovations are sequential, proprietary strategies may cause welfare reductions by blocking the second generation inventions that is necessary for the follow on research (Bessen and Maskin, 2009) yet openness is the key strategy for social welfare and industry profit (Scotchmer, 2010).

To understand the open source phenomenon and to export it to other research domains where " ‘‘source code’’ no longer refers to software per se, ... it is often necessary to revisit the relevant licenses, the relevant infrastructures, and the relevant modes of collaboration in order to ask whether ‘‘open source’’ is possible in the same manner." (Lounsbury et al., 2009, p.59). Therefore, in the following section, we start our analysis by examining the origins of open source phenomenon in software industry, revise the motivations for contributing to open source projects at both individual and firm level and then carry our analysis beyond software by examining the common characteristics of open source innovations (Pénin, 2009).

Section 3 discusses the co-existence of patents and open source innovations from different point of views. Section 4, examines an open source technology transfer (OSTT) model that might be used in an academic setting for transferring a technology beyond software to firms. By focusing on the case of sequential innovations, two alternative licensing strategies with different degrees of exclusivity, namely open source licensing (with a "viral" clause) versus exclusive licensing, are compared. Section 5 concludes.

2. Understanding the Open Source Phenomenon : Software and Beyond

2.1. A Brief History of Free Open Source Software (FOSS)

The emergence and development of open source software in academic settings such as MIT and Berkeley or central corporate research facilities such as Bell Laboratories dates back to the era of 1960s and 1970s, where no ground rules or legal protection existed for collectively developed software (Lerner and Tirole, 2000). The appropriation of the operating system UNIX, which had collectively developed by academic and corporate researchers at AT&T's Bell Laboratories, by the AT&T through the enforcement of IPR urged the foundation of Free Software Foundation (FSF)[2] by Richard Stallman of the MIT Artificial Intelligence Laboratory in 1983 (Lerner and Tirole, 2004). The foundation set the philosophical as well as legal ground for free (libre) software[3]. In order to protect collectively developed software from future appropriation and keep the software free, a formal licensing procedure named General Public License (GPL), which is also known as "copyleft" was introduced. This license initially introduced for the computer operating system called GNU (GNU's not Unix) in order to maintain its source code[4] to remain open to the users. GPL allows free use, free modification, free distribution of the source code as well as free distribution of the modified source code. GPL is a "viral" license meaning that all the derivatives or modifications to the original source code licensed under GPL should also be licensed under the same terms of GPL in order to maintain its freedom. GPL is also a specific coordination mechanism that can increase the number of contributors to open source projects and can sustain collective knowledge production (Gambardella and Hall, 2006).

Starting with the widespread diffusion of internet in early 1990s, volume of contributors as well as number of open source projects increased. The kernel of GNU operating system called Linux[5], which is independently developed by Linus Torvalds, also introduced in this era. Along with the increase in

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[2] Richard Stallman differentiates between the open source movement and free software movement claiming that the former missing the ethical point while focusing on the development methodology. Despite standing on different philosophical grounds, both movement comes together for various projects and consider the proprietary software as main enemy. For detailed discussion see: http://www.gnu.org/philosophy/free-software-for-freedom.html (accessed on November 10, 2015).

[3] Free software is used in the sense that "libre" software not necessarily "gratis" software. So it is all about freedom, not price. The famous analogy used by free software movement is " 'free' as in 'free speech' not as in 'free beer' " (GNU Project, The Free Software Definition, http://www.gnu.org/philosophy/free-sw.html.en, accessed on November 10, 2015).

[4] Source code is the human readable instructions or text written by using a specific computer language. The source code is transformed through a compiler to machine readable binary code which comprised of zeros and ones.

[5] Linux is not the name of the operating system but the name of the kernel of GNU operating system. Therefore, while mentioning the whole operating system it is correct and fair to use GNU/Linux as suggested by FSF. For more detailed discussion see: http://www.gnu.org/gnu/gnu-linux-faq.html.en (accessed on November 10, 2015).

the volume of projects, alternative less constraining licensing approaches such as LGPL (Lesser General Public License) , BSD (Berkeley Software Distribution) proliferated leading a way to "Open Source Definition" in 1997, the widely accepted criteria for open source software licenses (Lerner and Tirole, 2000).

2.2. Individual and Firm Level Incentives to Participate in Open Source Projects

Open source phenomenon, in comparison to proprietary mode of production and innovation, initially remained as a puzzle for economists (Lerner and Tirole, 2000). It indeed relies on specific incentives that are often non directly monetary and on specific mode of coordination based on knowledge communities. It also relies on specific intellectual property licenses. In an innovative environment, if the innovative process heavily depends on the prior knowledge, which is the case for sequential or cumulative inventions, then the traditional use of patents and copyrights may deter inventive activity since the right holder cannot automatically identify the future developers or whom to license. On the other hand in an open source regime there is no need for such an identification as the disclosure is automatic and hence there is no need to search for whom to disclose the knowledge. Such a disclosure is still possible without harming the contribution incentives to open source projects (Maurer and Scotchmer, 2006).

The incentives to contribute to the open source projects are analyzed at individual and corporate level. The initial literature focused on the intrinsic and extrinsic motivations at individual level. The most prominent motives behind the contribution of open source communities are: education, skill improvement, intellectual curiosity, the need to solve own specific programming needs, enjoying puzzle-solving, obligation/community incentive, recognition by peers, job market signaling (Raymond, 1999; Lerner and Tirole, 2000; Lakhani and Von Hippel, 2003; Lakhani and Wolf, 2003; Bonaccorsi and Rossi, 2004; Lerner and Tirole, 2004; Maurer and Scotchmer, 2006).

Yet the most stunning fact is the remarkable investments and contributions of large for-profit software (and software-embedded) firms such as IBM, Hewlett-Packard, Computer Associates and Novell to open source projects even if they may be the direct competitors of open source providers (Bessen, 2005). One of the motivations behind the corporate level contributions and releasing the source code for free is to get the bugs fixed quickly as "given enough eyeballs, all bugs are shallow" (Raymond, 1999). Other is to get improvements and feedbacks from open source communities without investing substantial amounts of costs (Bonaccorsi and Rossi, 2003b, Maurer and Scotchmer, 2006). On the contrary keeping the source code secret requires employing additional staff to fix the bugs, to update the software or to respond to users' needs (Lounsbury et al., 2009). Another is providing complementary services and products that are compatible with the open source product. This strategy is similar with the one that used by Gillette company that is giving away the razor in order to sell more razor blades. Firms also tend to release the source code if their product is lagging behind the leader. For instance, Netscape's decision to release the portion of its browser Mozilla's source code allowed the complementary segment of the company to be utilized widely in open source projects and hence increased its profitability (Lerner and Tirole, 2004). Further, surveys show that firms encourage their software programmers to participate in open source projects even within the working hours which may allow the companies to learn more about the open source world and their development approach (Lakhani and Wolf, 2003). There are also surveys showing that commercial firms use the open source collaborations as a way to find new and talented workers

(Bonaccorsi and Rossi, 2003b; Henkel, 2006). Achieving a good market position through network externalities (Schmidt and Schnitzer, 2004), influencing the standards (von Hippel, 2002; Varian and Shapiro, 2003), blocking the market dominance by large proprietary software firms (Kogut and Metiu, 2000) are among the other strategic reasons of firms' participating in open source collaborations.

Maurer and Scotchmer (2006, p.7) put forward that "open source incentives will not work if the open source software must itself be a profit center. This is because imitation is its very life blood. Instead, the open source activity must be complementary with something that remains proprietary." This is somehow explains the incentive puzzle behind the open source regime and how firms still stay profitable.

2.3. Open Source Model Beyond Software

A combination of bazaar mode of organization (Raymond, 1999), which refers to an open, interactive and non-hierarchical organizational design; of open disclosure of the software source code and of a legal ground in the form of copyleft type of license brought about the success behind the open source movement in software industry (Pénin,2011). This success immediately raised the issue of exporting the model to other sectors as diverse as biotechnology, pharmaceuticals, nanotechnology online encyclopedias such as Wikipedia, geographic information systems, 3D printing, open source vehicles and the growing number of research discuss the possible application of open source model to specific industries (Maurer, 2003; Maurer and Scotchmer, 2006; Lakhani and Panetta, 2007; Pénin and Wack, 2008; Lounsbury et al., 2009; Sugumaran, 2012). Regarding the quality concerns over open source outputs, for instance in the case of on-line encyclopedia Wikipedia, Maurer and Scotchmer (2006, p.28) states that " its accuracy is comparable to its most prestigious IP-supported counterpart*, Encyclopedia Britannica.*" by relying their argument on the recent peer review tests (Giles, 2005).

However the scholars are skeptic about whether other sectors can also provide a favorable environment for proliferation of open source projects. For instance Lerner and Tirole (2004) claims that many biotechnology tasks cannot be broken up into independent and manageable "modules" and not all the users are sophisticated enough to customize the molecules to their own specific needs. In a similar way Kogut and Metiu (2001) assert the non-modularity of a molecule. As a counter argument Maurer and Scotchmer (2006, p.29) claims that " The existence of “me-too” drugs, in which drug companies change existing patented compounds just enough to avoid patent infringement suggests that molecules may be more “modular” than Kogut and Metiu suspect." Further, Maurer (2006) discusses the divisibility of drug discovery process explaining that the companies routinely break the process into subtasks some of which may be performed as open source collaborations. Nevertheless they claim that even if the convincing examples of open source biology is yet non-existent, the similar incentives driving the contributions of software programmers may also exist for biologists (Maurer and Scotchmer, 2006).

Yet, a convincing example to open source biology may be BIOS (Pénin and Wack, 2008; Pénin, 2011). BIOS ("Biological Innovation for Open Society" or "Biological Open Source") is an initiative of non-profit organization Cambia, aiming at finding solutions to inequities in biological innovations, mainly in the field of agronomy, through a decentralized innovation. The initiative advocates an innovation paradigm based on open source, open science and open society as well as on licenses that promotes the use, improvement and the share of technology (BIOS website)[6].

However there still exists discussions on the term "open source" when it is applied beyond software. Although some scholars (e.g. Rai, 2005; Boettiger and Burk 2004) argue that the bioinformatics software projects and science collaborations adopting open source type licensing terms such as HapMap license can be labeled as "open source biology", Maurer (2003) states that bioinformatics is indistinguishable from any other software and the open science collaborations are fundamentally similar to the traditional science projects of 1930s, thus making the term open source "a matter of semantics" (Maurer and Scotchmer, 2006, p.29). To clarify the term "open source" it is then appropriate to ask what is the source code of non-software innovations. Lounsbury et al. (2009) asks this question for the nanotechnology, where they discuss the possibility of an open source nanotechnology project. In the engineering domain, they suggest that the "source code" may include technical designs, schematics or for a software embedded engineering material it is the actual source code of the software. When the nanotechnology is applied to the domain of materials chemistry then the source code may be the detailed instructions for the materials and the steps used in the process of material synthesis. One of the recent open source hardware projects initiated by Open Source Hardware Association (OSHWA) defines the source code of a hardware (machines, devices or other physical objects) as "the design from which it is made" (OSHWA website)[7]. Lounsbury et al. (2009) makes it clear by explaining what makes any form of open "source code" different from "a static publication of a method" (Lounsbury et al. 2009, p.60) is that its aspects allowing easy and legal sharing, modification, encouraging reciprocal contributions as well as collective learning which thus makes open source inventions dynamic .

Thus, identifying the aforementioned common aspects leading to the success of open source movement is helpful for carrying the model beyond software. Pénin (2011) explores whether the general principles behind the success of the free open source software (FOSS) can be applied in other sectors. He suggests (Pénin, 2009; 2011) a definition of "open source innovation (OSI)", which substantially differs from open innovation (Chesbrough, 2006) and encompasses all open source-like production models including FOSS as well as open science, collective invention (Allen, 1983) and user centered innovation. As put forward by the prior literature, FOSS stands on three pillars: technical, organizational and legal (Raymond,1999; Lerner and Tirole, 2001; Bonaccorsi and Rossi, 2003a; Lakhani and Wolf, 2003). Free (libre) and open source code constructs the technical pillar; collective, interactive and non-hierarchical bazaar mode of organization constructs the organizational pillar and finally an original "viral" GPL license constructs the legal pillar through a special use of software copyrights in a way that neutralizing its proprietary effect and protecting the software and its all derivatives against the future appropriation. All these three core dimensions assure the, openness, interactivity and the freedom of the system. Thus, through the generalization of FOSS, Pénin (2009; 2011) suggests that an innovation process can be "open source" if (i) all the actors of the innovation process voluntarily disclose the knowledge that they produce just as the developers release the source code of software (ii) innovating actors continuously interact in a bazaar mode of organization (iii) knowledge produced remains open to everyone without any discrimination.

[6] http://www.bios.net/daisy/bios/home.html (Accessed on November 13, 2015).
[7] http://www.oshwa.org/definition/ (Accessed on November 21, 2015).

3. Open Source and Patents

3.1. Patents as "Bottlenecks"

An important question arising in this context is whether patents and open source innovations can co-exist. The common view is that patents and open source cannot co-exist because traditionally patents are tools used for appropriating the research results and exclude others from using them. Therefore whereas proprietary innovation refers to "patented" innovation, in most of the case the automatic assumption behind open source innovations is that they are "unpatented" and hence in the public domain. For that reason patents are perceived as kind of "litmus paper" showing whether the system is proprietary or open source.

It is indeed the case that traditional use of patents may slow down or block the innovation process when the inventions are sequential and create monopoly deadweight loss. To illustrate this argument, we can look at software industry, where the innovations are sequential, highly complex, and has very high speed of progress. For the case of software, the granting of patents are quite debatable. In Europe, although it is blurry, European Patent Office (EPO) states that the software is not patentable but copyrightable. However, EPO finds the term software ambiguous so replaces it with a new concept called "computer-implemented invention"[8] and not strongly closes its doors to software patents. On the other hand in U.S, software is both patentable and copyrightable. In compare to copyrights, which protects the expressions, patents protect the ideas. So, in the case of software each protects the different parts of the software. Copyright protects against the duplication of text-like source code, whereas a patent protects the idea embedded in a software such as a graphical design or an algorithm. For instance jpeg and LZW algorithm used in gif is protected by patents (Stallman, 2002). So when we imagine how many patents software programmers try not to infringe, it is not difficult to guess how the patents may dramatically slow down the progress of such a dynamic complex industry.

To emphasize the danger of software patents Stallman (2002) makes an analogy with musical symphony, which combines many musical ideas just as the software combines many ideas. Then describes an imaginary case where the governments of Europe in 1700s decide to implement patents on musical ideas. That is to say, for instance, sequence of notes or rhythmic patterns could be patented. And he makes the case even more striking by stating that:

> *"Now imagine that it's 1800 and you're Beethoven, and you want to write a symphony. You're going to find it's much harder to write a symphony you don't get sued for than to write one that sounds good, because you have to thread your way around all the patents that exist. If you complained about this, the patent holders would say, "Oh, Beethoven, you're just jealous because we had these ideas first. Why don't you go and think of some ideas of your own?" "*
>
> Stallman (2002, p.157-158)

[8] For further discussion on software or "computer-implemented invention" patents see: https://www.epo.org/news-issues/issues/software.html (Accessed on November 12, 2015).

Further, he adds:

> *"But nobody, not even a Beethoven, is such a genius that he could reinvent music from zero, not using any of the well-known ideas, and make something that people would want to listen to. And nobody is such a genius he could reinvent computing from zero, not using any of the well-known ideas, and make something that people want to use."*

Stallman (2002, p.158)

But notwithstanding, with the aim of increasing innovative activity, series of legislations promoting the strengthening of software patents passed during the 1980s and 1990s in U.S. It is showed that, contrary to its initial aim, such legislations hindered the innovative activity because of sequential and complementary nature of the inventions in software industry (Bessen and Hunt, 2007). Similar problem may also exist in other domains, where inventions are sequential, as for instance biotechnology. This problem mainly stems from the fact that when the inventions are sequential, patents give a holdup right over the first generation invention that may impede the incentives to produce second generation inventions (Belleflame and Peitz, 2010). When patents are used as tools to induce monopolies by exerting exclusive rights on the first generation inventions they increase the cost of accessing to past technology and hence they can be bottlenecks. Therefore the common view in the literature is that open source and patents should not co-exist especially when the innovations are sequential.

3.2. Patents as "Legal Jujitsu"

Against the common belief an adequate use of patents may be necessary in open source innovations beyond software, where copyrights can no longer be used as a protection mechanism, since patents are flexible instruments that may serve diverse purposes (Pénin and Wack , 2008). For instance, Pénin and Wack (2008) claim that patents may preserve the freedom of access to upstream research tools for the case which they call "free-libre biotechnology". Just as in the case of open source software copyrights, which are used as tools to prevent from future appropriation by waiving "all rights reserved" provision (O'Mahony, 2003), in the case of sequential research tools they suggest the use of patents in a form of "legal jujitsu" (Benkler, 2006), through the analogy of Japanese martial art Jujitsu used for active self defense. In principle, such a use is possible through a standard open source patent license (Lounsbury et al., 2009) which is yet non-existent though. It is indeed the provisions taking place in these sort of licenses that really bound the users and even the owner of the exclusive right as long as the right holder waives any rights preventing the freedom of access ,modification and distribution of the invention. Thus a copyleft type of license requiring the further improvements to the patented research tools to be put back into the common research pool through the adoption of a "grant back mechanism" (Boettiger and Burk, 2004) may coincide with such an ideal.

Similarly David (2006) mentions " the third face of IPR" making them flexible instruments to "expand the commons for science" by stating that :

> *"It is, like the application of certain forms of copyright licensing – such as the GNU GPL in the case of open source software, a form of 'legal jujitsu', Yochai Benkler's (2006) marvelously acute characterization of the strategy of deploying the law intellectual*

property rights to achieve a purpose quite opposite to the one for which is usually is intended." "

David (2006, p.2)

An example defending the co-existence of patents with open source innovations is from pharmaceutical industry, namely the Open Source Drug Discovery (OSDD) Project of the Council of Scientific and Industrial Research of India. OSDD promotes patenting of drugs for neglected diseases such as malaria and tuberculosis seen mostly in developing countries. Thus the project "aims at converging patents and open-source innovations" (Sugumaran, 2012, p.1638) through viral licenses like GPL to ensure affordability and accessibility of such drugs without enforcing price monopolies. Another example is for open source hardware project. OSHWA explains why they need patents (OSHWA website)[9]. The very first reason is to make openness "sticky" through creating enforceable copyleft or viral license. Thus they aim at using patent licenses for defensive reasons in order to "avoid having open source hardware patented by another party." Although the copyright protects the design of the hardware it does not protect the hardware itself as it is a physical object. Thus, in this case patents serve for the same purpose just copyrights do for open source software which is creating a "sticky" open system and to enforce it to other parties through viral clauses.

A misleading inherent assumption is that knowledge is automatically in the public domain if it is not privately protected. However what is socially desirable is to make knowledge to remain in the public domain and this could be achieved by assigning property rights to the public or to the institutions aiming at preserving the public nature of the knowledge (for instance universities) instead of only to private agents, since IPR should not only be thought of exclusive rights to the private agents (Gambardella and Hall, 2006). Thus, in compare to open access licenses or to putting the knowledge into the public domain, enforcing copyleft type licenses could ensure the persistence of the whole system to remain free by preventing the future appropriation of the upstream knowledge. Enforcing a viral clause becomes especially important in the case of sequential inventions where the second generation inventions build on the first generation invention (Pénin and Wack, 2008).

Thus, in the case of sequential inventions, when used as a "legal jujitsu" patents may foster open source innovations rather than becoming a bottleneck . What guarantees such a promise of free and open system with patents is that waiving the traditional exclusive rights hindering follow-on research through the use of copyleft type standard patent licenses.

4. Towards University Based Open Source Technology Transfer (OSTT)

4.1. Technology Licensing with Different Degrees of Exclusivity[10]

With the aim of making public research organizations (PROs) to contribute more to economic development, in the last few decades, universities all around the world have been encouraged to valorize their research results by national and regional governments through transferring their technology to the industry. This valorization process has been accelerated with the legislations such as Bayh Dole Act passed in 1980 in U.S and law on research and innovation passed in 1999 in France.

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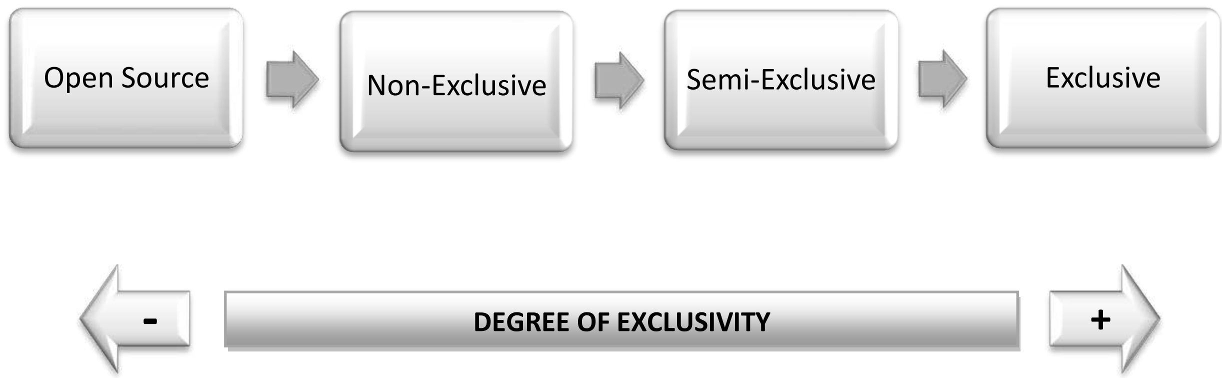
[9] http://www.oshwa.org/2013/12/05/open-hardware-legal-meetup-nyu-nov-11/ (Accessed on November 21, 2015).

[10] This section is mainly based on the discussions in Öcalan-Özel and Pénin (2015).

One of the prominent technology transfer mechanisms, which is largely privileged by universities and policy makers, is formal licensing contracts along with a systematic increase in university patenting all over the world (Mowery et al., 2001; Azagra-Caro et al., 2006; Carayol, 2007; Lissoni et al., 2008).

Depending on the degree of exclusivity (Cameron, 2010), a licensing contract may range from an exclusive license to an open source license (see figure 1). In an exclusive license, the licensor (university) grants a monopoly right to the licensee (firm) over the use of an invention which may eventually result in the exclusion of even the right holder[11] (the university) whereas in open source licensing 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 and Hall, 2006). Therefore open source licensing is the least exclusive form of licensing. In between these two extremes, many different degrees of exclusivity can take place. For instance universities may grant license to several firms at the same time through non-exclusive licenses. Universities may also grant an exclusivity over the specific use of a technology in one sector (exclusive license per field of use), may restrict the use in particular territory or may limit the time of exclusivity. These are the licenses with restricted exclusivity terms and thus called semi-exclusive licenses.

Figure 1: Degrees of Exclusivity (Öcalan-Özel and Pénin, 2015)



The decision to grant an exclusive versus non-exclusive or semi-exclusive or open source license may have important implications on the performance of the technology transfer as well as on social welfare. On the one hand exclusive licenses may be required to incentivize firms to invest in the development of embryonic inventions (Jensen and Thursby, 2001), while on the other hand it may induce monopoly deadweight loss (Colyvas et al., 2002). Therefore university faces with a trade-off between incentivizing firms to invest in their technology (dynamic efficiency) and reducing the monopoly deadweight loss (static efficiency). However a licensing decision must be tailored depending on the context. That is to say various determinants such as nature of invention, technological regime, competition regime (Pénin, 2010) and firm related characteristics should enter into the licensing decision process.

[11] In exclusive licensing contracts, university often include a clause stating that the university can continue to perform research after the granting of exclusivity to the firm. However this is not always the case in every single exclusive licensing contracts. There is always a risk that exclusive licensing may prevent or limit the upstream knowledge production and its diffusion as well as it may do so for the production and diffusion of downstream innovations depending on the knowledge characteristics and market structure.

To illustrate this, we may refer to a historical example, where the nature of the invention was highly effective on the patenting and licensing decision of the university. In this example we also see how “the third face" of patents was used in compatible with the social mission of the university. In 1922, University of Toronto (UT) got a patent on insulin and its manufacturing methods and extended its patents to many countries even though medical ethics did not allow universities applying patents on medical inventions (Cassier and Sinding, 2008). However university's intention was to use its patents for the public interest through controlling the standards and quality of the drugs and preventing any monopoly that may limit the accessibility of drug. In order to administrate the use of patent portfolio for the public interest, UT set up an Insulin Committee which consisted of university governors, insulin discoverers, and then grew with the inclusion of industry members and patent attorneys in addition to researchers and academicians. Cassier and Sinding (2008) explains one of the novelties in the UT's patent policy as such:

> *"The insulin patenting policy helped to shift the commonly accepted norms in the medical profession and academic world: rather than refusing IP rights altogether, it could be useful to own a patent for the sake of medical ethics and to protect patients. The idea here was not to use the power of the patent to create a commercial monopoly or to extract a rent, but to make it the instrument of a drug biopolicy inspired by the public good. To that end, intellectual property had to be free of commercial goals, monopolies on production and sale, profit-sharing for inventors, and perhaps the collection of royalties."*
>
> Cassier and Sinding (2008, p.166)

Given the embryonic state of the invention, which was still in experimental phase and industrial scale tests were necessary, one year exclusive license was given to Eli Lilly to incentivize the firm to invest in the further development of the invention. After a limited exclusivity, UT licensed the invention and its improvements non-exclusively to many other companies. Thus, UT managed to keep its invention to remain accessible through the use of non-exclusive license with grant-back mechanisms which make this licensing scheme very close to open-source licenses. Therefore insulin case may be, considered as the ancestor of open source-like licensing based on patents in a sector other than software. However, we should note that non-exclusive license, in compare to an open source license, may still be discriminatory regarding the number of firms accessing the technology can be restricted by the university in principle. Nevertheless, a mixed licensing policy, tailoring the licensing decision to the specific needs of the technology and grant back requirement of the improvements did indeed proved to be successful in terms of further development and wide accessibility of insulin.

4.2. University Based Open Source Technology Transfer (OSTT)

Today, most of the technology producing universities delegate the mission of transferring their technology to the managerial units called Technology Transfer Office (TTO). Further recent reforms tend to delegate these missions to independent TTOs (for example SATT in France) whose objective is more or less explicitly to be profitable (Öcalan-Özel and Pénin, 2015). Therefore one of the ongoing debates over the primary objective of TTOs is whether to continue adopting a more profit-driven TTO or more socially driven TTO when it comes to transferring publicly-funded university research results. What may cure this dilemma is introducing an open source technology transfer (OSTT) model. Open source licensing strategies might be used with conventional licensing strategies by tailoring the licensing decision depending on the context.

For now, as a part of university technology transfer policy, application of open source licenses are rather limited in number and confined to software. This is partly because of this new mode of technology transfer puzzles TTOs as well. But on the other hand, in comparison to open transfer models, traditional transfer is highly restrictive, discriminatory and usually associated with high transaction costs. For these reasons, Dalle and Rousseau (2004), suggest a dual licensing scheme by mixing traditional technology transfer with a new "academic public license" to decrease high transfer costs and to increase more open collaborative research development platform. This duality is rather based on the idea of "segmenting between markets with different products". That is to say a viral license for the academic version of the technology and a traditional licensing scheme for the commercial versions allowing private actors to have a "complementary proprietary module". Even though this dual licensing scheme initially suggested for software, it is also indicated that a dual transfer mechanism could also be possible beyond software, for example for the cases of educational resources or biotech databases.

However when it comes to transferring a technology other than software based on similar terms taking place in open source licenses, our knowledge is limited since there does not yet exist such an example in practice so far. To the best of our knowledge, theoretical research developing policies on open source technology transfer from university to industry is also rather limited. A research by Lounsbury et al. (2009) suggests alternative technology transfer models for the case of open source nanotechnology. Nanotechnology focuses on nanometer scale inventions which has commercial applications as diverse as lighter and more durable sports equipments, wear-resistant tiers, stain-resistant clothing, cosmetics as well as applications for national defense. Governments of developed countries invest huge amounts of money as a result of increasing nano race. For such profitable technologies, the research highlights the current fact that university TTOs are relying more on traditional transfer models aiming at maximizing their profits and use their IP portfolios to serve to that end. By examining a specific invention in the domain of materials chemistry related to a process of arsenic removal developed at Rice University -a project which they claim to be the first candidate for open source nanotechnology- they suggest that open source approaches may be possible for certain technologies and even superior to the existing traditional transfer models. The research also suggests that TTOs may still continue using patent metrics as long as "number of users of a patent" are counted as a measure of success instead of revenue from patents. To capture the value coming from "number of users of a patent" they claim that the university should license its patents non-exclusively[12] either for free or for a very low fee with grant back provisions. They also suggest a dual-licensing scheme, in which the TTOs license their patents non-exclusively with GPL-like restrictions and require an additional "non-GPL license fee" for firms who do not want such a restriction. So that,

[12] In a non-exclusive license with grant back provision, even though the number of licensees are sufficiently large, it can still be discriminatory in the sense that university may still exclude some firms to get a license for its invention, whereas an open source license wouldn't allow this discriminatory scenario. Because when the invention licensed open source, it means that the licensee does not need to get a permission from the principal for the use of that invention and as long as the licensee stick with the terms of the license, she can continue using it. But since we do not yet have a standardized patent based open source license, non-exclusive license with a large number of licensees and grant back provision may be considered as a proxy for it in practice for now.

instead of "betting on a single licensee" by granting the firm an exclusive license and expecting the invention to be commercialized, the university TTO will distribute such a risk by "betting on many horses" in an open source transfer model (Lounsbury et al., 2009). As a result this alternative open source model would allow benefiting from socially valuable uses of knowledge and creates a more competitive innovation-based economy.

Open source transfer may also be nuanced regarding the restrictiveness of the license to ensure incentives. Gambardella and Hall (2006) distinguishes between "upstream" and "downstream" activities. They put forward that even though GPL may be an effective coordination mechanism for the production of public goods, it may not be so effective if the important complementary investment for downstream activity is necessary. When considerable amount of investment is necessary, they suggest allowing degree of privatization by using less restrictive open source licenses (e.g. LGPL) so that firms can raise resources needed for investment but when such downstream investments are less important, GPL can still be more socially desirable.

Thus, compatible with the social mission of universities, it is expected that university TTOs should develop alternative ways of transferring their technology. The alternative open source transfer models can be mixed with traditional transfer models. However, choice of a transfer strategy depends on many factors but prominently on the characteristics of the technology. Therefore, in the next section, we discuss the importance of open source technology transfer in the case of "sequential" inventions.

4.3. Open Source Licensing in the Case of Sequential Inventions

In this section, among various other determinants that may enter into the licensing decisions of a university, we focus on the case of sequential inventions and discuss whether adopting an open source licensing strategy may be welfare increasing in a sequential setting. A sequential invention is a kind of cumulative invention[13] where “each successive invention builds on the preceding one” (Bessen and Maskin, 2009, p.612). Thus we can think of a first-generation invention as the seed of a second generation invention. Unless the seed exists, follow on inventions are non-existent. Therefore especially in the case of upstream knowledge for the generation of which universities play the major role, it is crucial to decide how to distribute the seeds for the production of downstream innovation to allow them growing into diverse forms of innovations increasing the social welfare.

By its very nature, the knowledge production is a cumulative process. In her seminal work, Scotchmer (1991) states that the innovation process is a cumulative action rather than an action in complete isolation by quoting to Sir Isaac Newton's famous expression: "If I have seen far, it is by standing on the shoulders of giants." It is indeed the case for many innovations. Cumulative (or sequential)

[13] Although the terms "cumulative" and "sequential" are sometimes used interchangeably in the literature, Belleflame and Peitz (2010) distinguishes between two types of cumulative inventions each of which may lead to different patent problems. The first one is "*sequential inventions*", in which a particular invention leads to **many** second generation inventions. To illustrate, the invention of laser lead to many second generation inventions such as spectroscopy, laser surgery or CDs/DVDs. In this case the main problem is the holdup right over the first generation invention that may impede the incentives to produce second generation inventions. The second one is "*complementary inventions*", in which a combination of **different** first-generation inventions enter as input to the production of a second-generation invention. For instance, to produce new peripherals to be combined with personal computers or video game consoles. In this case the main problem is "tragedy of anticommons" (Heller and Eisenberg, 1998) caused by patent thickets.

innovations are quite common in sectors such as information technologies and biotechnology (Belleflame and Peitz, 2010). In the software sector for instance, VisiCalc (Visible Calculator) was the first spreadsheet program which became the seed of the Lotus spreadsheet and then the Lotus became the basis for Microsoft's Excel (Bessen and Maskin, 2009). Similarly in biotechnology, a technique for inserting viral DNA into bacterial DNA, known as recombinant DNA (rDNA), developed by Herbert Boyer and Stanley Cohen in the early 1970s, has become the seed to the works of most molecular biologists in various sectors. Pénin and Wack (2008) gives this technique as an example of a research tool, which is itself not an application but rather an input or a part of a sequential process of innovation. In a context, where there exists many research trajectories that involves uncertainty, a variety of actors will follow different research paths (Nelson and Winter, 1982). Therefore it is crucial to keep all the research paths open to the highest number of participants by allowing the research tools to remain free (libre) through the use of patents as a "legal jujitsu" in such a sequential setting (Pénin and Wack, 2008). Their research suggests universities and public research organizations alternative ways to use their patent portfolios in a sequential setting since wide dissemination of university technology can be achieved through GPL type open source licensing of these patents. Polanski (2007) considers a model with sequence of innovations where he compares the performance of proprietary licensing with the GPL. His findings suggest that proprietary licensing may end the sequential innovations at very early phases because of holding-up problem. For the projects that are sufficiently convex (meaning that increasing returns to scale) and modular (meaning that projects with high number of development stages) open source mechanism is found be successful for sustaining sequential knowledge production.

From the view point of the firm, licensing the university technology based on viral open source licensing terms may reduce the short-run profit along with an increasing competition and hence may deter incentives to invest in open-sourced technologies. However in a sequential setting, such a competition raises the probability of follow-on innovations and increases the firm profit in the long run (Bessen and Maskin, 2009). Profitability could also increase with more product differentiation (Belleflamme and Peitz, 2010). Higher the product differentiation, more independent the demands to the products. Further differentiated products give a way to different R&D paths and increase innovative complementarities and hence technological diversity (Bessen and Maskin, 2009). Yet another factor increasing the profits in a sequential setting may arise from cost reduction (Scotchmer, 2010). Collective nature of open source innovations allow larger contributions to common knowledge pool through grant back requirement of university open source licenses. Knowledge will flow freely between university and firms as well as among firms. In turn this may decrease the research and development costs of the innovating firms and decrease the time to market of the innovations. Moreover, industry profit may be higher under a GPL regime. Scotchmer (2010) shows that, even if proprietary licensing yields larger profits for the first innovator, it creates larger profit losses for second innovators than the profit gain for first innovator. Thus, she asserts that a commitment to GPL as a whole industry is more advantageous in a sequential setting and the second generation invention can be made compatible only if the first generation technology is open for follow-on research .

Open source transfer strategies may also promote the competitive power of young small firms. By using open source licensing as a transfer mechanism, university allows small size firms or new born start-up firms with limited resources to access the university technology freely (without discrimination) and this might be a springboard for such firms to compete or even catch-up with large incumbent firms. Indeed in a sequential setting, even if open source licensing might not initially be effective for incentivizing large number of firms to invest in first generation university technology, it might still incentivize small start-ups who have closer ties with university and then may attract large incumbent firms to join the collective innovation chain for producing next generation technologies.

On the other hand, although exclusive license may seem to be the most lucrative deal for the firm in the short run (but also for the university TTO as it usually yields larger licensing revenues), in terms of incentivizing the firms to invest in university inventions and enjoy monopoly profit over the life time of exclusivity; in the long run, when the invention is sequential, it may block second generation inventions coming to the market. Thus the economic problem will be more than a trade-off between dynamic and static efficiency but a trade-off between short run and long run dynamic efficiency. Exclusive license will deter innovation incentives for second generation innovations (long run dynamic efficiency) since the first generation innovation is monopolized (short run dynamic efficiency).

Thus when university commit to a viral GPL in a sequential setting, the probability that second generation innovations will come to the market is higher. Such an open transfer mechanism increases the social value of an innovation and hence the social welfare by allowing compatibility of sequential innovations (Scothchmer,2010).

Below, Table 1 summarizes the section by comparing two extreme, alternative patent-based licensing strategies that can be used by a university TTO.

Table1: Comparing University Technology Transfer Strategies: Open Source Licensing (with "viral" clause) versus Exclusive Licensing

Open source licensing (open source technology transfer)	**Exclusive licensing (traditional technology transfer)**
Free (libre) and open knowledge flow	Knowledge flow is restricted
Non-discriminatory	Discriminatory
Grant-back requirement	No grant-back requirement
Promote collective knowledge production	Does not promote collective knowledge production
Continuous interaction (dynamic)	Not interactive (static)
Patents as "legal jujitsu"	Patents for attacking
More compatible with university social mission	Less compatible with university social mission
Yields higher number of users	Yields higher licensing fee in the short-run
Promotes static efficiency and long-run dynamic efficiency	Promotes short-run dynamic efficiency

Allows compatibility of second generation technologies	Blocks compatibility of second generation technologies
May increase social welfare when the invention is sequential	May decrease social welfare when the invention is sequential

5. Conclusion

It is not surprising that the open source movement proliferated in an academic setting, in "the republic of science" (Polanyi, 2000 [1962]), where knowledge production is primarily driven by non-monetary incentives. The movement has grown further in the hands of independent software developer communities relying on a specific non-hierarchical mode of organization, but also attracted for-profit firms to join open source projects for various reasons. The bazaar mode of organization along with an open source code and specific use of intellectual property licenses brought about its success. The success of free open source software (FOSS) movement immediately raised the issue of exporting it to other industries (Pénin, 2011).

In this paper we examined the "open source" concept beyond software and discuss the possibility of universities using the open source technology transfer (OSTT) mechanism as an alternative to traditional technology transfer. Instead of relying solely upon exclusive licenses we suggest university TTOs to tailor their licensing strategy depending on the context. Therefore we emphasize when the technology is sequential, university TTOs should consider using open source licenses with "viral" clauses. Our prediction is that in a sequential setting, openness of the first invention developed by the university will allow the development of second generation inventions.

We also insist on the co-existence of patents and open source innovations (with the exception of software). Patents, just as copyrights for software, can be used as "legal jujitsu" (Benkler, 2006) to avoid future appropriation when coupled with appropriate copyleft type licensing and preserve the freedom of the system in a sequential setting. Thus contrary to the possibility of appropriation of further developments when the first generation invention is put in the public domain, patents as a legal pillar guarantees openness through binding all the agents of an innovation process. Compatible with its social mission, universities should employ copyleft type open source licensing as a part of their technology transfer strategy, especially when the inventions are sequential. Even if this may seem to be challenging for incentivizing firms to invest at the initial stage, the success of FOSS in motivating the firms to invest in open source projects indicates that this scenario is possible for other technologies, as long as the complementary investments are not too high (Gambardella and Hall,2006).

This paper, as a first step, discussed the issue of transferring university based sequential open source innovation other than software, even if in practice such a case is yet non-existent. This paper contributes to the literature through a conceptual discussion on university open source technology transfer (OSTT) beyond software and through comparing a patent-based OSTT with the traditional technology transfer in the case of sequential inventions. Thus, we focus on the condition (i.e. if the invention is sequential) under which OSTT may be more efficient than the traditional mode of transfer (i.e. exclusive licensing) while a similar research (see Dalle and Rousseau, 2004) focus more on the conditions under which OSTT can be made more efficient, in an academic setting.

However to justify our arguments, we need an economic model analyzing the conditions under which OSTT can be welfare increasing in compare to an exclusive license in a sequential setting. Thus the next step for completing this work will be building a game-theoretic model played between a university and firms, where university wants to transfer a sequential invention to the industry. Since sequentiality is only one of the determinants among many other factors affecting a licensing strategy of a university TTO, further research suggest various lines of inquiry. An interesting one could be examining the effect of "network externalities" as a determinant of firms' investing in university technology when university wants to open source its technology.

References

Allen, R. C. (1983). Collective invention. Journal of Economic Behavior & Organization, 4(1), 1-24.

Azagra-Caro, J. M., Carayol, N., & Llerena, P. (2006). Patent production at a European research university: exploratory evidence at the laboratory level. The Journal of Technology Transfer, 31(2), 257-268.

Belleflame, P., & Peitz, M. (2010). Intellectual Property. In Industrial Organization: Markets and Strategies (pp.505-542), Cambridge University Press.

Benkler, Y., (2006). Freedom in the commons: A political economy of information. Yale University Press.

Bessen, J., & Hunt, R. M. (2007). An empirical look at software patents.Journal of Economics & Management Strategy, 16(1), 157-189. Bessen, J. E. (2005). Open source software: Free provision of complex public goods. Available at SSRN 588763.

Bessen, J., & Maskin, E. (2009). Sequential innovation, patents, and imitation.The RAND Journal of Economics, 40(4), 611-635.

Boettiger, S., & Burk, D. L. (2004). Open source patenting. Journal of International Biotechnology Law, 1, 221-231.

Bonaccorsi, A. and C. Rossi (2004) "Altruistic individuals, selfish firms? The structure of motivation in Open Source software", First Monday, 9(1), accessible at http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1113/1033 (current Feb.14, 2010).

Bonaccorsi, A., & Rossi, C. (2003a). Why open source software can succeed.Research policy, 32(7), 1243-1258.

Bonnacorsi, A. and C. Rossi, (2003b), Licensing Schemes in the Production and Distribution of Open Source Software: An Empirical Investigation, Sant' Ana School for Advanced Studies Institute for Informatics and Telematics Mimeo.

Cameron,D. M. (2010). Cameron's Canadian Patent and Trade Secrets Law. Chapter 13: Licensing. Retrieved 06, June 2014 from http://www.jurisdiction.com/patweb13.pdf.

Carayol, N. (2007). Academic incentives, research organization and patenting at a large French university. Econ. Innov. New Techn., 16(2), 119-138.

Cassier, M., & Sinding, C. (2008). 'Patenting in the public interest:'administration of insulin patents by the University of Toronto. History and Technology, 24(2), 153-171.

Chesbrough, H. W. (2006). Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R. R., Rosenberg, N., & Sampat, B. N. (2002). How do university inventions get into practice?. Management science, 48(1), 61-72.

Dalle, J. M., & Rousseau, G. (2004). Toward collaborative open-source technology transfer. Feller et al.[74], 34-42.

David, P. A. (2006, September). Using IPR to expand the research common for Science: New moves in ‘legal jujitsu’. In Proceedings of the Conference Intellectual Property Rights for Business and Society, September (pp. 14-15).

Gambardella, A., & Hall, B. H. (2006). Proprietary versus public domain licensing of software and research products. Research Policy, 35(6), 875-892.

Giles, J. (2005). Internet encyclopaedias go head to head. Nature, 438(7070), 900-901.

Heller, M. A., & Eisenberg, R. S. (1998). Can patents deter innovation? The anticommons in biomedical research. Science, 280(5364), 698-701.

Henkel, J. (2006). Selective revealing in open innovation processes: The case of embedded Linux. Research policy, 35(7), 953-969.

Jensen, R., & Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. American Economic Review, 91(1), 240-259.

Kogut, B., & Metiu, A. (2000). The emergence of E-Innovation: Insights from open source software development. Philadelphia: Wharton School, University of Pennsylvania.

Kogut, B., & Metiu, A. (2001). Open-source software development and distributed innovation. Oxford Review of Economic Policy, 17(2), 248-264.

Lakhani, K. R., & Panetta, J. A. (2007). The principles of distributed innovation.innovations, 2(3), 97-112.

Lakhani, K. R., & Von Hippel, E. (2003). How open source software works:“free” user-to-user assistance. Research policy, 32(6), 923-943.

Lakhani, K., & Wolf, R. G. (2003). Why hackers do what they do: Understanding motivation and effort in free/open source software projects. MIT Sloan Working Paper No. 4425-03

Lerner, J., & Tirole, J. (2001). The open source movement: Key research questions. European Economic Review, 45(4), 819-826.

Lerner, J., & Tirole, J. (2004). The economics of technology sharing: Open source and beyond (No. w10956). National Bureau of Economic Research.

Lerner, J., & Triole, J. (2000). The simple economics of open source (No. w7600). National Bureau of Economic Research.

Lissoni, F., Llerena, P., McKelvey, M., & Sanditov, B. (2008). Academic patenting in Europe: new evidence from the KEINS database. Research Evaluation, 17(2), 87-102.

Lounsbury, M., Kelty, C., Yavuz, C. T., & Colvin, V. L. (2009). Towards open source nano: Arsenic removal and alternative models of technology transfer.Advances in the Study of Entrepreneurship, Innovation and Economic Growth,19, 51-78.

Maurer, S. (2006). Other Business: Choosing the Right Investment Strategy for Tropical Disease Research. Bill Gates, Who Bulletin (forthcoming).

Maurer, S. M. (2003, November). New institutions for doing science: From databases to open source biology. In European Policy for Intellectual Property Conference, Maastricht.

Maurer, S. M., & Scotchmer, S. (2006). Open source software: the new intellectual property paradigm (No. w12148). National Bureau of Economic Research.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2001). The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980. Research policy, 30(1), 99-119.

Nelson, R. R., & Winter, S. G. (1982). An evolutionary theory of economic change, 929-964.

O'Mahony, S. (2003). Guarding the commons: How community managed software projects protect their work. Research Policy, 32, 1179–1198.

Öcalan-Özel S. & Pénin (2015, January). An Economic Analysis of Optimal University Licensing Strategies. In DRUID Academy Conference, Aalborg.

Pénin, J. (2009). Open source innovation: Rethinking the concept of openness in innovation Studies. submitted to Revue Économique.

Pénin, J. (2010). Quelle politique de licence de brevet pour les organismes publics de recherche? Exclusivité versus modèles plus ouverts. Management international/Gestiòn Internacional/International Management, 14(3), 47-58.

Pénin, J. (2011). Open source innovation: Towards a generalization of the open source model beyond software. Revue d'économie industrielle, (136), 65-88.

Pénin, J., & Wack, J. P. (2008). Research tool patents and free-libre biotechnology: A suggested unified framework. Research Policy, 37(10), 1909-1921.

Polanski, A. (2007). IS THE GENERAL PUBLIC LICENCE A RATIONAL CHOICE?*. The Journal of Industrial Economics, 55(4), 691-714.

Polanyi, M. (2000 [1962]). The republic of science: Its political and economic theory.Minerva, 38(1), 1-21.

Rai, A. K. (2005). Open and collaborative research: A new model for biomedicine. Intellectual Property Rights in Frontier Industries: Software and Biotechnology, Robert Hahn, ed., AEI-Brookings Press, Washington DC.

Raymond, E. (1999). The cathedral and the bazaar. Knowledge, Technology & Policy, 12(3), 23-49.

Schmidt, K. M., & Schnitzer, M. (2004). Public subsidies for open source? Some economic policy issues of the software market. University of Munich Dept. of Economics Mimeo.

Scotchmer, S. (1991). Standing on the shoulders of giants: cumulative research and the patent law. The Journal of Economic Perspectives, 29-41.

Scotchmer, S. (2010). Openness, open source, and the veil of ignorance. American Economic Association.

Stallman, R. (2002). Free software, free society: Selected essays of Richard M. Stallman. Lulu. com.

Sugumaran, G. (2012). Open Source Drug Discovery-redefining IPR through open source innovations. Curr Sci, 102, 1637-9.

Varian, H. R., & Shapiro, C. (2003). Linux adoption in the public sector: An economic analysis. Manuscript. University of California, Berkeley.

Von Hippel, E. A. (2002). Open source projects as horizontal innovation networks-by and for users. MIT Sloan School of Management Working Paper No. 4366-02.