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Research Tool Patents and Free-Libre Biotechnology: A Unified Perspective

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Abstract

This paper proposes a unified conceptual framework to analyse the multiple role and consequences of patents in the case of biotechnology research tools. We argue that the knowledge/information and independent/complementary nature of research tools define heterogeneous frameworks in which the patent system plays different roles. In particular, using the analogy with the free-libre open source movement in software, we show that patents can promote open innovation by ensuring the freedom of some pieces of knowledge. A strong conclusion of the paper is therefore that, against common belief, an adequate use of the patent system may contribute to preserving freedom of access to upstream research tools within a framework that we call free-libre biotechnology.

Keywords: Intellectual property rights, sequential innovation, open source, life science, collective invention
JEL classification: D2, O3

1. Introduction

This paper proposes a unified conceptual framework to analyse the multiple role and consequences of patents when innovation is sequential, i.e. when second stage innovations build on first stage innovations. Specifically, we consider the case of biotechnology research tools, which are inputs into the process of developing new biotech drugs, plants, etc. Using the analogy with the free-libre open source movement in software, we propose an enlarged view of the patent system by arguing that patents can provide different solutions when confronted with varied situations (Cohen *et al.*, 2000; Arora *et al.*, 2003; Bureth *et al.*, 2005).

In particular, we assume that the knowledge/information and independent/complementary nature of research tools define heterogeneous frameworks and in each of these frameworks the patent system plays a different role. A strong conclusion of the paper is that, against common belief, an adequate use of the patent system may contribute to preserving free access to research tools within a framework that we call free-libre biotechnology (Burk, 2002; Maurer, 2003; Burk and Boettiger, 2004; David, 2006).

There has been a recent focus of attention on research tools within academic and policy-related literature, as indicated by the abundant literature on research tools (NRC, 1997; Heller

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and Eisenberg, 1998; Walsh, Arora and Cohen, 2003; Nelson, 2004). Research tools foundational position within the innovation process in modern biotechnology makes their mode of appropriation a core issue. Since they are inputs in the innovation process, strategies of exclusion based on strong patents may impede second stage innovations that need to use research tools. Conversely, lack of an adequate appropriation environment may decrease the incentives to construct research tools. A fine balance must therefore be respected when dealing with the issue of research tool patents[1].

Regarding the double objective to allow for a wide use of research tools and to provide firms with incentives to innovate and build new research tools, we explore in this paper the solution provided by the pioneering example of free-libre open source software (FLOSS). It may indeed be appealing to transpose the FLOSS model to biotechnology research tools since detailed analyses of the software industry suggest that FLOSS can provide a solution to reconcile incentives to innovate with wide dissemination of software outputs in a context of sequential innovation.

The FLOSS movement was developed in the 1980s and was linked to the emergence of strategies of appropriation and exclusion within the software industry[2] (Lessig, 2001). Worried about the consequences of the surge in appropriation, which may deter collaborations and open access to software, Richard Stallman founded the Free Software Foundation (FSF) in 1984. The latter aimed at promoting collective and decentralised development of software and specifically of free software, an important feature of which was disclosure of the source code[3]. In order to ensure the freedom (in the sense of the French meaning of the word, i.e. *libre* and not *gratuit*) of software the FSF developed an original exploitation licence: The General Public Licence (GPL) also known as copyleft. The GPL ensures that everybody can use, modify, copy and even distribute any software "protected" by the licence under the unique condition that these changes continue to be copylefted, meaning that improvements must remain accessible and open to modifications by everybody. GPL is therefore a viral license since it reproduces itself with each modified or extended version of software that used copylefted software. In the last decade FLOSS has proved to be a major success with some libre-software, such as Linux, Apache, Sendmail, MySQL and Perl (LAMP), widely adopted all around the planet.

FLOSS, in part due to its commercial success, have triggered a tremendous number of studies (Lerner and Tirole, 2001 and 2002; Nuvolari, 2001; Bonaccorsi and Rossi, 2002; Dalle and Jullien, 2003; Lakhani and von Hippel, 2003; Jullien and Zimermann, 2006). This interest is understandable since FLOSS proposes a radically new vision on organisations and more

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[1] The question of the effect of patents on incentives to produce and circulate research tool is far from straightforward. As emphasised by many examples, a wide circulation of the research tools based on low licensing fees does not mean to renounce making important profits out of the research tool (see for instance the Cohen-Boyer patent on recombinant DNA). Similarly, high licensing fees may not always prevent the diffusion of the research tool (as suggested by the example of the Polymerase Chain Reaction (PCR) technology) (NRC, 1997).

[2] The 1980s saw the emergence of the first patents for software. Initially software was considered to depend exclusively on copyright legislation due to its algorithmic content. But following the Diamond vs. Diehr case (1981), patents began to be granted to software designers who could also continue to be granted copyrights (since patents and copyrights protect two different parts of the software). Software can therefore be given a double layer of protection: a patent for its design, and a copyright for the source code and this without any requirement to disclose the source code.

[3] Following Maurer (2003), in the broadest sense open source software are any software published with human readable source code. Hence, OSS may not necessarily be free but free software, by definition, includes the disclosure of the source code.

specifically new insights regarding the incentives that drive individuals and the way they interact.

The question of incentives to participate in FLOSS project has been studied not only for the individuals, for whom intrinsic motivations may play a major role, but also for firms. The latter have developed business models that enable them to derive money from participation to FLOSS (Lerner and Tirole, 2001; Jullien and Zimermann, 2006). Even though the underlying software is open source, i.e. anyone can view and copy it, a firm's revenue can be based on the services and products that it provides complementary to the software such as installation, teaching manuals, teaching courses, customisation and security, other complementary software, etc. In other words, firms that join the OSS movement usually make money by providing services or products associated with the software and not by selling the software itself, which therefore does not need to be protected.

Empirical and theoretical studies suggest that FLOSS may reconcile the apparently opposite goals of providing incentives to do research and ensuring a wide dissemination of the research results. Applying the principles of FLOSS to research tools is therefore appealing because the patent system does not appear to provide a satisfying balance between the necessary freedom of use of research tools and the incentives to produce those tools. Although the central role of patents in the birth and development of the biotechnology industry three decades ago is not questioned, there are many concerns nowadays that research tools are over protected and that too strong patents lead to restricting access to materials and techniques that are critical for future research and therefore may impede the pace of innovation in life sciences (Heller and Eisenberg, 1998; Nelson, 2004).

Yet, since research tools are inputs in the development of further applications it is highly important that they remain easily available. We propose therefore the elaboration of a framework based on the example of FLOSS that would favour collaboration, collective innovation and ensure the freedom of research tools. This framework we call free-libre biotechnology. As copyright in software has been turn to copyleft, we show that patents can be turned in such a way to ensure free utilisation of research tools and therefore can help to promote free-libre biotechnology. Patents are flexible instruments that can be used in multiple manners. As David (2006) proposes, one can envisage hijacking the traditional role of patents by "using IPR to expand the commons for science":

> *"Less notice has been taken, however, of what may be called "the third face of IPR." This is the legal protection of private rights to arrange contracts for common-use, thereby creating "club goods" that permit the participants to share access to the information and its utilization under conditions that emulate those of the public domain, but which may be enforced by invoking the rights of the original intellectual property owners. The contractually constructed, IPR-based "information commons", thus, is a natural device for the socially efficient pooling of research results, particularly those that take the form of tools for exploratory science. 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) marvellously 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)

This possibly new role for the patent system leads us to propose a unified framework to analyse the many different uses of patent with respect to research tools. We consider two dimensions of research tools: as complementary vs. independent in use and knowledge based vs. information based, which defines four very different contexts for conceptualising research tools. For each one of these contexts, we analyse the role of the patent system and discuss the strengths and weaknesses of this instrument. The basic idea being that the more we converge towards a complementary and knowledge based view of research tools, the more important it is to guarantee the freedom of research tools.

Section 2 defines research tools and discusses the merits of patents with respect to the production and distribution of research tools. Section 3 introduces and discusses, through various examples, the notion of free-libre biotechnology. Specifically it explores the role of patents to promote the construction and preservation of a common, open platform of research tools. Finally, in section 4 we propose a framework to analyse the role of patents according to two dimensions of research tools - complementary vs. independent and knowledge vs. information based.

2. Research tools and the patent issue

A research tool is used for research purposes and is not considered, in its own right, as an application. In particular, research tools are knowledge that may either be: embodied, such as in scientific instruments and research materials; or disembodied, such as a technique employed during research (Scotchmer, 2004). Specifically, in biomedical science a research tool is “any tangible or informational input into the process of discovering a drug or any other medical therapy or method of diagnosing disease” (Walsh, Arora and Cohen, 2003).

Research tools are part of a sequential process of innovation, being situated upstream from the development of applications such as new drugs for instance. These follow-on innovations are thus drawn from the previous invention, diffusion and usage of research tools. In clear, research tools serve as a springboard, lay foundations for downstream innovations. Researchers are in a sense consumers of research tools. This attribute of research tools as feeding further research has led the academic literature to refer to research tools as: “enabling technologies” (Burk and Boettiger, 2004) or “platform-technologies” (Pray and Naseem, 2005).

Examples of research tools are many. For instance, the technique of recombinant DNA invented by Stanley Cohen and Robert Boyer is a research tool that has proved to be essential in the spawning of advances in molecular biology (National Research Council, 1997; Oliver and Liebeskind, 2003). This technique is essential in the manipulation of DNA segments but, in itself, it is not an application. It is of great usefulness only in upstream research tasks. Likewise, instruments in spectroscopy concerning the study of matter generate usefulness predominantly in research activities. The continued innovation in spectroscopy and the embodiment of this knowledge into scientific instruments has led to many advances (Riggs and von Hippel, 1994). Other examples of biotechnology research tools are polymerase chain reaction (PCR), high-throughput screening technologies, genomic databases, transgenic mice, modelling programs or knowledge of a target that is involved in a disease and as such represents a potential drug intervention.

In the context of sequential innovation, where the value of an invention may be in boosting further innovation, the question of the adequate patent dimension is as vital as it is delicate (Scotchmer, 1991; Green and Scotchmer, 1995; Scotchmer, 1996; Bessen and Maskin, 2000; Scotchmer, 2004). A first generation research tool is an essential element to develop a second generation application. In this situation, the development of the application is not possible without the prior invention of the research tool. However, since commercial value usually resides in products that are developed later and not in the research tool itself, the invention of the research tool will only be rewarded if there is a part of appropriation of the returns from the sale of the application. A central point is hence to make sure that earlier innovators are compensated for their contribution, while ensuring that later innovators have also an incentive to innovate.

Intellectual property can manage to organise the division of profit among sequential innovators. The patenting of the research tool allows for the negotiation of "reach-through" licensing terms between the two entities. Scotchmer (1991) insists on the importance of the scope of the research tool patent in determining the redistribution of the value from the sale of the second generation application. Too broad a patent will lead to excessive appropriation by the research tool inventor and insufficient returns for the second generation inventor. Whereas if it is too narrow, then the application may be able to work around altogether the research tool patent thus not rewarding the first generation inventor at all. In short, the design of patents is essential in ensuring sufficient incentives to invent for both the first and second generation inventors.

Furthermore, the search process of research paths involves, by nature, uncertainty, since at the onset it is impossible for any one participant to foresee the most performing trajectory. As a matter of fact, a variety of participants will interpret differently what they believe to be the best path to pursue (Simon, 1982; Nelson and Winter, 1982). It is thus socially desirable in this context of uncertainty that numerous entities partake in the search of a particular research path in order to find the most performing one (Merges and Nelson, 1994). For this to be so, the research tools essential to the domain must not remain exclusive to a few so that there can be numerous forages into the research path (Nelson, 2004). In the language of the commons, research tools must be *free* in order to keep research paths open to numerous participants and a jubilant search process can hope to find the best paths to pursue.

Yet, patents on research tools give rise to an element of *control* to the patent owner who has the choice to exert rights to exclude others from the concerned research paths. Therefore, research tool patents may influence the development of research tools and applications along technological trajectories (Dosi, 1988; David, 2004). Too wide patents may decrease incentives to set-up follow-on innovation because the latter may be held hostage by the first generation patent holder. Patents on research tools, and the consequent necessity of extensive licensing, invariably raise the cost for other participants to participate in the construction of a trajectory. If there are many such "toll booths" (David, 2004, p. 17) then it is likely that only the research paths that will lead to the highest and most certain payoffs will be trodden. Paths where the prospective payoffs may be bleaker or are of a highly exploratory and uncertain nature may not be pursued. In addition, the prospect of negotiating numerous licenses and the extensive transaction costs involved, such as legal fees, further put off participation in research paths that involve the licensing of many patents. Concerning the domain of biomedical science, this issue has been expressed as a potential "tragedy of the anticommons" where progress is hindered by the existence of multiple marginalisation, transaction costs and the potential breakdown of negotiations (Heller and Eisenberg, 1998).

In short, with regard to biotechnology research tools, patents offer contrasted results. On the one hand, there is no doubt that they increase incentives to produce first generation innovation. It is widely acknowledged that patents are essential elements to spur biomedical innovation (Levin *et al.*, 1987; Cohen *et al.*, 2000). But on the other hand, there are concerns that in life science we may have gone too far into offering patent protection and that patents may increase the cost of access to research tools, which may preclude further second generation innovations (NRC, 1997; Heller and Eisenberg, 1998; Nelson, 2004; David, 2006). In a recent study, Walsh, Arora and Cohen (2003) do not find evidence of such a retard due to research tool patents, mainly because actors of the innovation process are able to develop "working solutions"[4]. But the authors conclude that despite their reassuring finding, "aggressive patent behaviours can always threat scientific basic research", which calls for "a continuous need for active defence of open science". Free-libre biotechnology pursues this objective. Specifically, it aims at reconciling two apparently contradictory goals: (1) To provide incentives to economic actors to engage into the production of further research tools and (2) to ensure the freedom of the produced research tools.

3. Free-libre biotechnology

3.1 Definition, objectives and functioning

In a recent paper Maurer (2003, p. 3) makes the following statement: "Several authors have recently suggested that a new method of doing science, variously called *open source genomics*, *open source biology*, or *open source biotech* is about to emerge. The idea is intriguing. Although currently confined to computer software, open source methods present an interesting alternative to traditional R&D institutions like intellectual property. So far, however, it is not clear what *open source biology* would actually look like. Articles describing open source biology typically point to (a) computer software written by and for biologists, or (b) projects where biologists publish data but waive intellectual property protection […] Somehow, one expects more".

Actually, Maurer *et al.* (2004, p. 183) envisage open source biotech as a: "decentralised web-based, community-wide effort, where scientists from laboratories, universities, institutes, and corporations could work together for a common cause". Hence, such an institution should be based on voluntary collaborations, it should be non-hierarchical and decentralized. While we fully agree on this description of free-libre biotech as involving collaboration among

[4] "We find that there has in fact been an increase in patents on the inputs to drug discovery ("research tools"). However, we find that drug discovery has not been substantially impeded by these changes. We do not observe as much breakdown or even restricted access to research tools as one might expect because firms and universities have been able to develop "working solutions" that allow their research to proceed. These working solutions combine taking licenses, inventing around patents, infringement (often informally invoking a research exemption), developing and using public tools, and challenging patents in court […] Many of our responding firms suggested that if a research tool was critical, they would buy access to it. We also observe that most of what might be called "general purpose" tools—tools that cut across numerous therapeutic and research applications that tend to be non-rival-in-use—tend to be licensed broadly" (Walsh, Arora and Cohen, 2003). Pray and Naseem (2005) also explored the consequences of patents in the development of rice genomics and plant transformation technologies. They also conclude that: "We find that patents were important in inducing private firms to develop these platform technologies […] We identified some examples of research that were slowed down by the patent on tools. However, our preliminary assessment of the evidence suggests that the benefits from patents on tools outweigh the costs" (Pray and Naseem, 2005, p 108).

heterogenous actors, we insist here on the fact that one of the central features of a so-called open source biotechnology must be the freedom of access to the research.

Following Lessig (2001), "a resource is "free" if (1) one can use it without the permission of anyone else; or (2) the permission one needs is granted neutrally" (Lessig, 2001; p. 12). This definition implies, among others, that the permission to access the resource is not granted at the discretion of an "owner", who could therefore choose arbitrarily to refuse or grant access to others. With respect to upstream research tools this definition of freedom has one important consequence: The access to the "free" research tool needs not automatically to be free of charge but the research tool must be available on "reasonable terms". Here, we converge with Nelson (2005, p. 137) who confesses that: "With respect to patented research tools created by industry research, my concern is less with open use at a fee, but with decisions not to make the tools widely available".

According to this definition, there can be free applications such as drugs for tropical diseases (Maurer *et al.*, 2004) or free research tools such as plant transformation techniques in the case of the Biological Innovation for Open Society (BIOS initiative). The only requirement is that the artefact remains accessible for everybody under conditions that are not too difficult to meet and not discriminatory. In this pursuit of ensuring freedom to biotech research tools, organizational designs and numerous licenses analogous to those used in FLOSS can be ported from the software sector to the biotech one.

First, it is important to notice that, in a sense, a patented research tool is by definition open source, since the application to a patent entails an obligation to disclose the innovation publicly. In this sense we prefer the term free-libre biotech to open source biotech, for the latter fails to emphasise the main purpose of the movement, which is not only the disclosure of the knowledge but also to ensure its freedom. One of the *raison d'être* of the patent system is to open the knowledge underlying inventions. Patent applications must contain an accurate description of the innovation which, eighteen month after the first application, is published, i.e. becomes available to everybody[5]. Therefore, like open source software that are disclosed with their underlying source code, thus allowing other programmers to learn on them, patents contain a description of the innovation they intend to protect, therefore participating to the dissemination of the protected knowledge within the economy (Burk and Boettiger, 2004). This disclosure is specifically important in the case of cumulative innovations, for which secrecy would highly damage technological progress.

Yet, when innovations are sequential, as for research tools and their applications, the disclosure of the knowledge underlying an innovation may not be sufficient. What is often needed is also that the upstream innovation itself is free so that the next stage innovation can be built upon it. This freedom may therefore be ensured by transposing some of the licenses that have proved workable in the case of free software. For instance, in the case of research collaboration this may simply concern the signing of a waiver agreement in which participants into the collaboration engage themselves not to patent their output, so that the latter remains free to re-use. This kind of agreement was used in the Alliance for Cell Signalling (Maurer *et al.*, 2004)[6]. A further license could be an "open access" type license (Guadamuz, 2006) in which licenses allow for the research tools to be openly accessible to all who wish to use them, without any constraint attached to the license.

[5] This disclosure requirement is an obligation in all major countries but in the USA where national application with no international extensions can remain secret until the patent is granted.
[6] www.AFCS.org

Keep the whole platform open. Those open source licence may ensure the freedom of a research tool but not of all the follow-on research tools. Yet, we believe that the purpose of free-libre biotechnology must be to ensure the freedom of all research tools, to keep the whole platform open and not only some parts of it. It is not enough to make sure that one research tool cannot be appropriated but all the research tools related to a given technology must be kept free.

In order to achieve the continued freedom of all research tools related to a given technology, patents can be used in a performance of legal jujitsu (Benkler, 2006). Patents can mimic copyleft type licenses by adopting a "grant back mechanism", which would imply that users of patented research tools may be granted a license only if they agree to put further improvements under the free regime (Burk and Boettiger, 2004). Such a research tool license would therefore stipulates that users of research tools are required to grant back the rights on follow-on inventions to original inventors. Given that the original inventor chooses to license freely the research tools, this viral clause effectively guarantees that the sequence of innovations arising from a research tool will be enduringly free to re-use to all those who abide by the licensing terms.

Compared to such viral licensing agreements, releasing merely the innovation into the public domain or granting an open access license are less efficient strategies. Indeed, the goal of free-libre biotechnology is to ensure the freedom not only of research tools but also of all the follow-on improvements stemming from this research tool. With respect to this purpose, releasing the research tool into the public domain, for instance, entails the risk that follow-on innovators appropriate some part of the set of research tools and therein control their use.

The rationale in using open source licenses can be understood through the analogy with jujitsu, which is a martial art oriented toward active self defence. Jujitsu practitioners are never offenders but once they are attacked they practice an active and rather offensive defence. Having developed several skilful techniques, they are experts in using the strength of their adversaries to beat them. Similarly for free-libre biotech, patent owners use the strength of the patent system against its primary purpose. In line with the state of mind of martial art practitioners, free-libre biotechnology therefore suggests to use the patent system to prevent that entire streams of research are closed down by patent tickets. Research tool inventors, being aware of potential pitfalls in the delicate construction of a common knowledge base[7], refer to their capacity in legal jujitsu to guarantee the enduring freedom to re-use "their" research tools. By doing this they contribute to halting a "closeting off", "blackening", "controlling" of what we see as an essential "open, whitespace, free" layer of research tools.

The following two examples of the BIOS initiative and the International HapMap project illustrate the application of these viral licenses that constitute the "third face" of IPRs according to David (2006).

3.2 Two examples

In the domain of agricultural biotechnology, the BIOS initiative – BIOS as Biological innovation for Open Society - aims at developing free plant transformation research tools in

[7] In particular, the possibility that the patenting of complementary, follow-on inventions adds an element of control over the free resource, leading therefore to progressive appropriation of what was at the onset a collective knowledge base.

view of their re-use to create applications such as improved strains of crops. Specifically, the BIOS initiative tries developing a set of research tools that would operate freely of current patents on plant transformation methods. The BIOS initiative currently covers 12 research tools including the techniques of Transbacter and the popular GUS gene reporter. Those research tools are all patented and can be used only under specific conditions. In order to use them, a third party has to agree to the BIOS license that adopts a copyleft style "grant back mechanism" forcing the licensors into agreeing to share back to the BIOS initiative the rights to re-use the improvements that are made to BIOS research tools. In a dynamic perspective, this creates an environment: "in which a material or invention can be improved by the ideas of many, but access is maintained for all who agree to the terms, without exclusive capture by anyone" (BIOS homepage[8]). Furthermore, although the use of BIOS patent is *libre* it may not necessarily be free of charge. Private members of OECD countries are required, in addition to agreeing with the licensing terms, to pay a participation fee.

This viral clause of licensing implies that research tools that build on a technology patented by BIOS cannot be appropriated. Yet, this regards only upstream research tools. The treatment of applications derived from those research tools is completely different. Developers of potential applications of the BIOS research tools have the liberty to individually control new strains of plants, through patents if so wished. This frontier put to the free environment is linked to the specific features of innovation in biotech. As emphasized by Maurer *et al.* (2004), there has to be some appropriation in the innovation process so that, at the end, firms are encouraged to put end products on the market. Indeed, although prices for equipment in biotechnology may be declining, there remain large costs in the development of biotech applications, such as the testing of drugs (Lerner and Tirole, 2004). Those costs mean that an organization that is based solely on the decentralized contributions by a community of private, garage-based scientists with intrinsic and, limited, extrinsic motivations, is unlikely to reach the commercial success of FLOSS projects. The BIOS initiative aims therefore at preserving the freedom only of upstream research tools, without impeding the commercial exploitation of their direct applications.

A similar kind of license that tries to dynamically protect the freedom of the sequence of developments of a research tool was used in the domain of human genetics by the International HapMap project. This project aimed at developing a database of haplotypes, which consist of variations in the human genome that can help researchers to inquire into hereditary, genetic diseases. The value of this data is in comparing multiple genomes from around the world. Therefore it requires collaboration between numerous laboratories around the world and it is essential that all haplotype information remains in one single database. However, during the construction of the database there is a risk that individual parties appropriate parts of the database either through patents or through database laws.

Therefore, a specific licensing agreement was designed with the aim of preserving the free use of the entire database. The HapMap license requires, instead of royalties, that the user of the database agrees not to appropriate the database, nor to exclude other parties from using the data. In addition, if the user passes on the data to a third party, the same license would apply, as well. In other words, the HapMap license tries to defend the free re-use of the database by

[8] http://www.bios.net (accessed [09/17/06]). It is further mentioned on the website that: "Instead of royalties, BIOS licensees must agree to legally binding conditions in order to obtain a license and access to the protected commons. These conditions are that improvements are shared and that licensees cannot appropriate the fundamental kernel of the technology and improvements exclusively for themselves".

blocking property rights that might affect its free re-use and is enduring in the sense that it reproduces itself with all uses of the data.

3.3 Where do we go from here?

Free-libre biotechnology has been compared to jujitsu. Yet, in martial arts, like all practices, there is a necessary preparation time or "training" before the correct performance can be attained. Although legal attacks on the GPL today seem to be adequately countered by the FLOSS movement, which has never seemed so strong, this rests much on the work of the FLOSS community over the last 20 years. The ex-ante job of developing the licensing mechanisms, of convincing the actors, of reconciling the incentives of the community with the pursuit of a particular project, etc., entails sunk costs and implies that such communities can only become operational after a long preparation time. One of the first and major tasks to implement free-libre biotech will hence be to imagine and design licences that are likely to be accepted by most players in the field. Well designed open-source licenses are central for the viability of free-libre biotechnology.

For instance, the case of BIOS licenses is very much tailored to the fact that the mother-owner CAMBIA (for Centre for the Application of Molecular Biology to International Agriculture) owned valuable intellectual property to build on and that the domain allows separating the application from the research tool (basically, new plants are applications and everything to make possible a new plant is research tool). Furthermore, in this case the potential problem of appropriating follow-on, complementary research tools was clearly identified by designers of the licence, who therefore effectively reacted through the design of a license that has particular demands concerning the appropriation of these improvements and the rights to their re-use. In this way, BIOS is able to guarantee that the research tools and continued development is enduringly free. But other contexts will be different and will require subtle modifications to the license. It may not be so easy to separate a free layer from the controlled layer as other situations may require more upstream appropriation due to the necessary investments to develop research tools.

A further need of biotechnology open source license shall deal with the specificities of the biotech field as compared to software. Licenses will have to consider the fact that research in biotech is often more costly than in software, where the sole cost for programmers is often the time they spent in front of their machines. Also, licenses shall be clearly oriented toward business. Free-libre biotechnology can only work if there is alternative opportunity of profits. As established by J. Hope (2003): "Key issues for advancing the open source biology analysis will be developing open source patent licenses and other licenses appropriate for biological subject matter assessing the importance of higher capital costs in biotech development and establishing whether or not there exist secondary markets for biotech services or other commercial offerings that might support business models along the lines that have proved successful in the software context". As illustrated by the BIOS case, free-libre biotech does not aim at ensuring the freedom of all life science products. Only upstream research tools need to be free.

A further and highly important part of the preparation stage will involve the diffusion of the licenses within the domain. Although single efforts are to be acknowledged for their individual worth, a collective innovation process means that there would have to be a commonality in the use of free licenses. Much as norms and rules are situated within communities, the adoption of open source licenses is likely to be localized in communities.

How this may spread through from community to community of different typologies is an interesting question to be pursued.

To summarise, we discussed here an original way to use the patent system. Contrary to its primary purpose, which is to exclude potential imitators and thus to enable innovators to appropriate their innovation, patents may also preclude appropriation and ensure the freedom of innovations. How can we reconcile this original use of patents with more traditional ones? Economic theory has indeed identified many different rationales for the patent system. It has been shown that patents may increase incentives to invest in innovative activities (the traditional arrovian argument), contribute to disseminating knowledge within an economy, help create a market for technologies (Arora and Fosfuri, 2000; Arora, Fosfuri and Gambardella, 2000), ease inter firms negotiations and collaborations (Bureth *et al.*, 2005) or signal competences (Pénin, 2005). Our goal in the next section is to construct a unified framework to analyse the role of patents with respect to biotech research tools. We propose that each particular use of patents may correspond to a specific situation that depends on the properties of research tools.

4. A unified framework to analyse research tool patents

4.1 Conceptualizing research tools

The variety of economic properties that one can attribute to research tools leads to subtleties in their analysis. In order to highlight the nuances, we shall examine research tools along two principal dimensions: First, we can consider research tools as being information, such as in the seminal work of Arrow (1962), or as being knowledge, following Nelson and Winter (1982). Second, research tools can be depicted as either independent or complementary inputs in the development of downstream applications.

Independent vs. complementary research tools

A first dimension that is central to understand the variety of research tools deals with their independent vs. complementary nature. An independent research tool can be used alone into the development of an application. It does not need to be combined with other research tools. Conversely, complementary research tools cannot be used by themselves. They are useful to develop applications only when they are combined with other research tools. As such, independent research tools have a direct value to their users while a research tool that is complementary: “has no value to the user at all unless the user has access to its complements” (Scotchmer, 2004, p. 144).

This design element of research tools as either an individual input or as complementary inputs affects the interdependency between research tool producers and developers of applications. On the one hand, an individual input leads to a simple one-to-one interaction between a research tool producer and potential developers. Hence, the latter may not need to bargain with several different research tools producers, which highly facilitates the development of applications. On the other hand, the design element of complementary research tools means that multiple inputs are required to develop a particular application. Therefore, developers will have to bargain with many different research tools producers, which may increase the overall price to develop applications and even jeopardize the development of some applications.

Information vs. knowledge based research tools

A second essential dimension of research tools deals with their contents, which can be assimilated either to information or to knowledge. In the former case, production and diffusion of research tools can be modelled by using the seminal framework defined by Arrow (1962). When considered as information, research tools share to some extent the properties of a public good. First, the research tool is non-rival in use, i.e. one person's using the research tool does not prohibit another from using the same research tool. Second, when considered as being information the research tool is non-exclusive, i.e. it is very difficult or even impossible to exclude individuals from re-using it.

Therefore, to consider research tools as information leads to a classical problem of incentives. Since new knowledge can hardly be appropriable by the innovator, incentives to invest in R&D are low and there will be an under-investment of resources into the invention of new research tools as compared to society's preferred level. Hence there is a rationale for state intervention to correct under-investment in research tools.

Assimilating research tools to knowledge leads to a quite different picture. The public good problem is not relevant any more, since knowledge is usually sticky, i.e. it is embodied within its holder and benefits other individuals only after a long and costly work of transmission and assimilation. To absorb some knowledge that is transmitted by a given source requires a cognitive re-appropriation by the receptor, which means that knowledge is, in a sense, "personal" (Polanyi, 1958). It cannot be fully replicated and transferred from one individual to another. Therefore, knowledge is to some extent appropriable or, at least, does not benefit other individuals easily.

When considering research tools as knowledge based, the inventor and society no longer face the prospect of the provision of a new public good. In this case, the challenge rather concerns the intricate task of the transmission of the research tool. In particular, the transmission of the knowledge based research tool may require a costly process of codification (Cowan *et al.*, 2000). Furthermore, in order to be able to use the research tool, the user is also required to be endowed with the necessary knowledge to understand the message and to absorb the knowledge embodied in the research tool (Cohen and Levinthal, 1989). Undertaking the transmission process of the research tool is therefore an essential but resource-consuming step for the inventor and the user(s).

For the research tool inventor, the priority is now to manage the transfer of his knowledge for its re-use in the development of an application. In this task, the fundamental problem is how to make oneself understood. Much as the musician who is new on the scene is required to play his music otherwise no one will listen and possibly enjoy it, inventors must undertake repeated investment in making themselves known and understood through "garnering interest" to their knowledge (Callon, 1999). Accordingly, this task requires making the research tool understandable as well as the enrolment of application developers to pay attention to the knowledge in view of its understanding and re-use (Amin and Cohendet, 2004). It is only after such a collaborative work that there is the possibility of coordinating the development of an application. Conversely, by considering research tools as information, this vital collaborative process of the inventor garnering interest is abstracted from the diffusion of research tools[9].

[9] The distinction we draw between knowledge and information can be understood through the difference between emergent and stable situations (Callon, 1999). Regarding research tools as information implies that we consider a stable environment where actors and techniques are known, i.e. research tools can be diffused easily.

In this context of research tools as knowledge, the risk is therefore that research tool inventors and users fail to construct a common knowledge base that makes the development of applications possible. The rationale for state intervention rests here on solving issues of collaboration between the actors with at the root the problem involving the transfer of the research tool from inventor to user(s). To summarise, one can represent research tools along two dimensions: information vs. knowledge based and individual vs. complementary. Crossing those two dimensions leads to four different conceptualizations of research tools.

Table 1: A quadrant to conceptualize research tools

Research tools as	**Independent**	**Complementary**
Information	**I** *Incentives*	**II** *Coordination*
Knowledge	**III** *Collaboration*	**IV** *Collective invention*

I. This configuration, where research tools are used individually and can be assimilated to information, corresponds to the traditional arrovian framework. Research tools are easily reproducible by a technician without any need of assistance, which implies that the main concern deals with incentives to produce such research tools since, as emphasised above, their appropriation is not straightforward. Exchange of those research tools on a market are typically confronted to the paradox of Arrow (1962). The difficulties to sell such research tools to users and therefore to make money out of the research tools may decrease the incentives to produce them.

II. This second configuration depicts research tools as being information and complementary. An example of such research tools is Polymerase Chain Reaction (NRC, 1997; Fore *et al.*, 2006). In the domain of molecular biology the use of PCR has applications in domains such as diagnosis of hereditary diseases or forensics. PCR is a complementary research tool in the sense that it can not be performed without the use of other research tools- the technique, material and instrument. Yet, these research tools can be easily transferred and re-used by mere technicians, which makes them comparable to information. Here the major concern deals not only with incentives but also with coordination problems, since for the user it is necessary to assemble many research tools. A deficit of coordination among the different producers and users may prevent the development of some applications.

Conversely, regarding research tools as knowledge means that we consider emergent stages, where an uncertain environment make processes of translation and enrolment all the more important. In such emergent stages, there is uncertainty with respect to the nature of the development of the research tool, since its potential value, uses and quality are not known and since the inventor himself is unknown (Cohendet *et al.*, 2006). In this context of heightened uncertainty, the diffusion of knowledge will be inhibited as a common knowledge base of the "embryonic" research tools is yet to be constructed (Amin and Cohendet, 2004). Actors must undertake the costly understanding of research tools with no idea about the research tool or the environment it will be used in.

III. Considering research tools as being independent and knowledge based emphasises the importance of collaboration among users and producers. Conversely to former cases, here the use of research tools is not possible without the assistance of the inventor or a trained engineer endowed with the personal knowledge to operate the research tool. There is little free-riding possible. Concerning the knowledge embodied in the instrument, the understanding of the artefact's intricacies remains the sole possession of the inventor, who therefore controls the reproduction of the instrument. It is only after an effort of learning that the user will be able to operate the research tool. The major concern here has shifted from incentives problems to problems of transfer of the research tool. It is necessary to set up a tight cooperation among producers and users in order to transfer the knowledge based research tool. The keyword here is therefore collaboration.

IV. Finally, research tools can be viewed as knowledge and complementary. This can be, for instance, research tools concerning plant transformation, in the domain of agricultural biotechnology, in which the BIOS initiative was developed. In this case, the problem is to develop and preserve a common base of knowledge to use the research tools. Applications can only be derived from a tight collaboration among all the research tools producers and application developers. This configuration may therefore correspond to what several authors refer to collective invention (Allen, 1983; Schrader, 1991; Nuvolari, 2001).

We have proposed here a classification of research tools into four categories. In the next section, we shall demonstrate, through this depiction of different conceptualizations of research tools, the varied uses of the patent. Depending on the information or knowledge and the independent or complementary view, the patenting of research tools follows either a classical logic of appropriation or a logic of collaboration and even of liberation of the patented knowledge.

4.2 Different roles for research tool patents

Independent and information based research tools: Incentives

The upper-left part of the quadrant depicts the traditional arrovian framework. Research tools are information, which implies that their commercialisation will be confronted to the paradox enounced by Arrow (1962), which can be summarised as follows: The decision to purchase and use a research tool depends on the user's ability to measure up its value and, thus, on possessing the information. But, if the information is already possessed by the user then there is no need for him to buy it anymore (Arrow, 1962). The characteristic of information as an economic good undermines the possibility to trade research tools on a market[10]. Hence, in this basic configuration, without property rights producers can hardly trade research tools to users. Since only the latter can derive profit out of the research tool, incentives to invest into the creation of first generation research tools remain very low.

[10] A famous illustration of this problem is given by Tirole (2003, p. 23) who tells us the story of Robert Kearns, the inventor of the windshield wiper. Having no possibilities to commercialise alone his invention Robert Kearns proposed collaboration to Ford, to whom he disclosed the idea and some of the technical aspects. Ford refused the collaboration and some time later introduced on the market a similar product with only slight technological differences.

Patents can provide a solution to this paradox. The combination of the elements of exclusivity and revealing inherent to a patent are essential with respect to the implementation of a market for information. The coupling of these two properties of disclosure and protection allows in some sense to solve the Arrow's paradox (1962). Patents both disclose and protect information, thus preventing free riding from occurring. They enable innovators to sell their innovation with the peace of mind that no entity will "hijack" it. Therefore, paradoxically, property rights may often favour information transfer. In a sense, the patent system allows the creation of a market for technologies and highly codified knowledge (Arora and Fosfuri, 2000; Arora, Fosfuri and Gambardella, 2000).

Patents effectively allow the research tool inventor to commodify his invention by stipulating the conditions of its re-use. In a sense patents enable the separation between users and producers allowing therefore gains in specialisation by the respective entities. In this context, the inexistence of patents would mean that the same entity would have to be both the producer and the user of the research tool. Patents provide incentives for some firm to specialise in the production of research tools, to patent their research tools and then, to sell them to users through licensing contracts that specify the price and the terms of the transaction[11]. As emphasised by Scotchmer (2004), within this simple configuration patents enable the sharing of the benefits along the invention chain, allowing remunerating upstream inventors, who would not be induced to invent otherwise. Patents permit the development of second generation applications and to re-distribute some part of the profits to the first generation research tool's inventor.

Yet, economic theory has also extensively demonstrated that the element of exclusivity granted to the patent owner generates a dead-weigh monopoly loss for society. Monopoly pricing will lead to under-using the research tool as compared with an ideal, i.e. some applications may not be implemented although socially desirable. This dead-weigh loss is usually considered as the price to pay on the short run to ensure ongoing technological progress and therefore increased welfare on the long run. To summarise, when research tools are considered as being information and independent, patents are a central device to share the benefits among innovators and to ensure that there will be investments in both first and second generation products whenever the benefits outweigh the costs.

Complementary and information based research tools: coordination

The upper-right part of the quadrant views research tools as being information based but complementary, which means that a user will need to combine different research tools and that one single research tool without its complements has no value at all for its user. In this case, there is still a problem of incentives and distribution of profit that can be solved by the implementation of a patent system as described above. But beyond this problem of incentives there is also a problem of coordination among the research tool users and the different producers.

This need of coordination can be solved (at least partly) by the patent system. Indeed, patents, by creating a market for research tools, may be a powerful device to coordinate innovative activities and to ensure that users can access all research tools. It is a central axiom of

[11] The drug development industry is a prime example where division of labour induced by patents has changed completely the organisation of research. Typically in the 1980s and 1990s, the biotech paradigm generated a division of labour between biotechnology firms specialised in drug discovery techniques on the one hand and pharmaceutical companies specialised in bringing the end-applications to market on the other hand. Patents help to structure the transactions among those two worlds by easing the transfer of patented new molecules.

standard economics that the market acts as a coordination device. The commodifying of inventions allows the market to be the coordination device for bringing together a large number of upstream sellers of research tools and buyers looking for developing applications. This allows a powerful decentralised guidance through price signals on research tool licenses. The prospect of selling licenses guides research tool inventors as these licenses enable the important re-distribution of the profits from the development of the second generation applications.

However, here the implementation of application may be confronted to a problem of “anticommons” (Heller and Eisenberg, 1998). The expression “tragedy of the anticommons” relies on the notion of “tragedy of the commons” stressed by Hardin (1968). As stated by this biologist, the lack of property rights on a common good can lead, if the good is used above its regenerative capacities, to its entire destruction. The idea of the anti-common tragedy deals with the exact reverse problem. In the case of fragmented property rights over a resource there is a risk of suboptimal use of this resource due to the addition of monopoly situations that may lead to too high an overall price to exploit the resource. A tragedy of the anti-commons therefore means that an application derived from research tools may not be implemented due to too high a price induced by the addition of monopoly positions on intermediate research tools.

A tragedy of the anticommons may therefore arise when an application requires the combination of a high number of research tools, each of them being patented and therefore sold independently of the others. This multiplication of transactions leads first, to an increase of transaction costs, the users of research tools being obliged to negotiate a license with each producer independently. But, most of all, this leads to a problem of multiple marginalisation, which was first raised by Cournot (1838) in his seminal contribution on the pricing of complementary intermediate goods[12]. Following Cournot, a surprising conclusion about licensing complementary goods is that the joint price is lower if they are sold as a unit by a single owner. Not only does collusion among research tool producers increases their profits, but it also decreases the overall price, thus benefiting users too (Cournot, 1838).

It is therefore in the interest of society that policy makers watch the risk of anticommons and, if necessary, try to improve interactions among research tools producers in order to decrease the overall price of developing applications. One widely debated solution to problems of anticommons lies in the implementation of patent pools. A patent pool is an agreement between two and more patent owners to licence one or more of their patents to another third parties, set-up specifically to administer the patent pool. Hence, patent users, instead of having to bargain access with several independent owners will have to negotiate access only with one single entity that is in charge of all the relevant patents.

Patent pools may therefore decrease transaction costs as well as multiple marginalisation problems. Yet, two problems may affect the benefits of patent pools for society. First, costs

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[12] Cournot (1838) showed that, in the case of complementary intermediate goods, sometimes one unique supplier (who has a monopoly position) is better for the overall social surplus than an addition of several independent suppliers. The explanation relies on the existence of negative externalities. When a research tool producer increases his price, he decreases the demand for research tools, which affects other research tool producers. This negative externality implies that independent research tool producers will tend to ask too high prices for their research tools as compared with an ideal. Collusion among research tool producers may hence force them to internalise the externality and therefore to decrease the price of each research tool and the overall price to develop applications.

for society may not be deleted but only displaced, since nothing is said on how research tool producers may bargain to set-up the patent pool. Second, public authorities must be very careful with anticompetitive behaviours. There is indeed a conflict between the formation of patent pools and antitrust policies. It is possible that patent pools are implemented not to solve anticommons but merely to decrease competition and to increase the margins of firms in the pool. Standard economic theory shows that patent pools are procompetitive and welfare increasing when gathering complementary patents but welfare decreasing when gathering substitute patents.

Independent and knowledge based research tools: Collaboration

So far, we have considered research tools as being information based and as such we have supposed that they shared, at least to some extent, the properties of a public good. This may be the case for generic knowledge already disseminated within an economy. Yet, in the case of emerging and radically new techniques it is doubtful that those two properties are satisfied. As argued by Callon (1993), a more detailed study of knowledge economic property tends to reverse the issue. The problem for innovators is less a capacity to claim ownership over knowledge, than being able to diffuse it, to explain it to others. The tacit aspect of knowledge gives rise to a problem therefore opposite to that raised by the classical theory. During the first phase of the creation of an innovation, when common language and schemes do not yet exist, knowledge is marked by strong rivalry (it is hard to reproduce it outside the local context where the discovery has been made) and strong exclusivity (the invention is linked to the tacit knowledge of the inventor).

In terms of risks for the innovator, it is therefore less likely that problems of free riders might occur than problems of not making himself understood and therefore of not being able to implement the new techniques due to a lack of common cognitive grounds. Any attempt to disseminate and therefore to trade a research tool requires important and difficult preliminary work, as knowledge tends to adhere to its human support; it is most of the time “sticky”. This leads to reconsidering in depth the issue of research tools production and utilisation and the role of patents. As argued by Cohendet *et al.* (2006), in a knowledge based context, strategies of collaboration tend to overcome strategies of exclusion.

As soon as research tools are considered as knowledge, the central concern is shifted from incentives and coordination problems to collaboration issues. It is only through in depth interaction among users and producers that research tools can be transferred. Mere licensing agreements are not sufficient to ensure the transfer of research tools because users usually do not have the ability to exploit them. They need assistance and face to face interactions to learn how to use the new technique. This does not mean that patents will be useless but it radically changes the role of patents and the way in which firms use their patent portfolios.

In a knowledge based context it is more important for innovators to ensure the diffusion of their innovation, to make them understood than to prevent imitation. Patents therefore are not used as tools of protection and exclusion to market technologies but rather as devices to collaborate and to diffuse knowledge. It is only when techniques become more mature and languages are shared, that the importance of patents as an instrument of exclusion increases.

Patents may enable collaborations and therefore facilitate the exchange of tacit knowledge through various mechanisms. First, patents may facilitate collaboration between research tool producers and users because they help partners to identify each other. Indeed, all patent applications are published eighteen months after the first application, which means that by screening patent databases firms can identify potential partners. This signalling dimension of patents is all the more important as firms evolve in a context of incomplete information, usually not being able to infer what other firms are doing. For isolated research tool producers, patenting their technology may therefore be a way to advertise it and to ease the finding of users (Pénin, 2005).

Second, patents are a way to structure complex interactions among firms. They constitute legal devices that can help to structure collaborations and facilitate negotiations between research tool users and producers. For instance, patents reduce the risks linked to collaboration, therefore inducing firms to participate in the venture. Indeed, R&D cooperation is a risky process in the sense that participants must often share parts of their most important intellectual assets. Since patents protect the knowledge held by a firm from plundering by her partners, they decrease the risk of opportunistic behaviours and of hold up of competences. It follows that firms protected by patents may be more willing to be involved in R&D cooperation (Ordover, 1991). Furthermore, patents may also ease the transfer of the tacit component of technologies by including clauses of assistance and of exchange of employees in licensing contracts (Foray, 2004). In this sense patents are not only devices to market technologies but they structure more in-depth interactions between research tool users and producers. They provide a legal framework for trading tacit knowledge. Finally, all along the collaboration, a patent can assist heterogeneous partners because they provide a common language that can be understood by many. A patent is therefore a key element in a shared culture, a prerequisite to bringing together actors around a common project. This is especially true for university-industry relationships, for which cultural differences may sometimes complicate the transfer of technology.

In conclusion, when research tools are considered as knowledge their transfer is more complex than when they are assumed to be mere information. Yet, patents can assist the exchange of knowledge based research tools between producers and users by signalling the research tool to potential users and by structuring complex transactions and collaborations. This role of patents to foster inter organisation collaborations has been raised by many empirical studies[13].

Complementary and knowledge based research tools: Collective invention

Considering research tools as knowledge based and complementary reveals not only the issue of making oneself understood but also, in a context of uncertainty and multiple interactions, the importance of the construction of common knowledge bases. Not only is knowledge sticky, but the exploitation of a research tool requires the combination with many other research tools, i.e. users will have to collaborate with many producers. The key-point here is

[13] For instance, Bureth, Pénin and Wolff (2006) consider the case of a small Alsatian start-up involved in the development and commercialisation of chemical based vectors that serve to transfer genes or other bio-molecules (proteins for instance) within cells in-vivo or in-vitro. Vectors are clearly research tools since they are useful for the development of follow-on medical applications. The vectors invented by this start-up are all patented. Furthermore, the firm is currently engaged in an important project of vaccine against HIV with US partners. The role of the start-up is to provide the vectors necessary to transfer the antigens and therefore to trigger the production of antibodies. Interviews with several executive managers of the start-up all suggest that patents played a central role in the collaboration: First, it is by screening patent databases that the US partners discovered the existence of the small Alsatian start-up. This clearly emphasises the importance of the signalling dimension of patents. Second, patents were important during the negotiation in order to smooth the difference of size between the partners. They provided the background for the negotiations. Here is therefore an example of transfer of research tools through tight collaboration made possible by the patent system.

therefore the construction and preservation of a common platform of knowledge on which applications can be generated.

Since applications can only be based upon full access to this common platform of knowledge formed by all the research tools, the open dimension of the platform is central in order to allow its access at the lowest cost. In collective invention knowledge is re-used and partakes in a plurality of research potentially leading to numerous new research tools and downstream applications. Research tools as a free-libre resource is where researchers are able to unabashedly tinker and experiment without the necessary permission of “someone”. This whitespace is the vital open and unobstructed part of the researcher's workspace used for creative endeavours. This research workspace can be seen as the layer preceding the development of follow-on inventions, i.e. the application layer. The importance of openness in such a complex and sequential innovation process was recently emphasised by Nelson (2004, p. 463), who reminds us that: “I do not know of a field of science where knowledge has increased cumulatively that has not been basically open”.

Yet, if the workspace is controlled through property rights then this will most likely narrow the domains of researchers as they will be forced down paths based on financial value and exclusive negotiations rather than on the creative value of the applications. Fragmentation and appropriation of the common knowledge base increases the cost of accessing it and therefore impedes the development of follow-on applications. Taking this perspective of research tools as knowledge and complementary leads therefore to identifying a problem of patents as potentially augmenting the difficulties to access existing knowledge, thus hindering the construction of a collective process of innovation. This is all the more relevant given the complementary nature of research tools, making each of them central in the development of applications. In the language of the commons, what would benefit extremely from being a free resource has a large propensity to be controlled through the attribution of patent rights on essential elements (complementary research tools).

In short, it is sometimes feared that patents may jeopardize the emergence of applications because they undermine the common platform of knowledge necessary to ensure interactions among research tool users and producers. The complementary nature of research tools and the need to re-use them in the attempt to form an understanding and develop designs, interfaces and standards, may be impeded by the use of aggressive patent strategies.

But, and this is the central idea defended in this paper, it is also possible that patents help to preserve the openness of the commons. The protection granted to the patent owner can serve to preserve the openness of a research tool and can therefore foster collaborations and exchanges among research tool users and producers. In this sense, research tool producers do not use their patents to exclude imitators but to ensure the freedom of use of the research in the domain. Hence, it is in this context of complementary and knowledge based research tools, in which it is central to preserve the openness of all first stage research to foster the development of applications, that the use of patents to preserve the freedom of first stage research may be necessary and that free-libre biotech may be a helpful concept.

To summarize, conceptualizing research tools in subtly different ways helps to understand the underlying rationale for the various uses of patents. Among others, based on the intuitions from the quadrant we developed a theoretical rationale for free-libre biotechnology. Taking the perspective of research tools as being information leads to an understanding of the paradox of Arrow and of the problem of appropriability, which the patent may solve. But in this framework there is no rationale for the freedom of research tools. Conversely, considering research tools as knowledge reveals the issue of the necessity to build a common knowledge base on which research tool users and producers will be able to interact. It is within this latter context that free-libre biotech is the most likely to emerge.

5. Conclusion

This paper dealt with the availability of upstream research tools and the role of patents to ensure or to hinder their accessibility. This issue is central since, on the one hand there is a strong and steady trend towards patenting upstream research in life science, and on the other hand in upstream domains it is central to preserve a minimum level of freedom to foster the production of downstream applications. It is therefore important to implement policy levers to ensure both that individuals have strong incentives to produce research tools and that those research tools are easily available to users. Our work on how patents may help to preserve freedom of upstream research can reconcile those two apparently contrasted objectives.

Patents do not automatically prevent access to biotechnology research tools. Making the analogy with FLOSS, we showed that patents can also be used in order to help making first stage innovation free and thus to facilitate the production of second stage innovations. One can operate the same hijacking of patents as has been done with the copyright to transform it into the so-called “copyleft”. The underlying approach to intellectual property rights that is embodied in FLOSS can serve as the inspirational basis for numerous free-libre biotechnology licenses that refer to how the rights to re-use an invention are attributed.

At one extreme, patents can be used to secure technology and to prevent other firms from using it but, at the other extreme they can serve to ensure the ongoing freedom of a specific stream of technology. The question we addressed then was when we shall observe a use of patents as instrument of exclusion and when we shall observe a use of patents as instrument to ensure free access. By crossing two dimensions of research tools – complementary vs. independent and information vs. knowledge based- we analysed four different situations in which patents may play very different roles. Specifically, we focused on the extreme case of collective invention, which appeared to us as a likely situation in which free-libre biotechnology may develop.

In conclusion, this paper showed that patents are very complex instruments that should not be reduced merely to tools of exclusion. Yet, some sceptical readers may want to question the applicability of free-libre biotechnology in reality. Our answer is twofold: First, such models of free-libre biotech already exist in reality as illustrated by the example of BIOS. Second, we do not pretend that free-libre biotech is the solution that should be implemented in all contexts. Rather, we tried to identify specific contexts in which this concept shall work[14].

[14] And we believe that this promising concept may be workable in some contexts. For instance, Janet Hope (2003) gives the following plausible scenario: Consider a small biotech company that generates revenue by exploiting a patenting technology. Only a small fraction of its revenues directly comes from licensing. The major source of revenue is derived from performing contract research and services. This company is engaging in research and development activities to improve the technology platform on which it is generating revenues. According to Hope, this imaginary company is likely to be a good candidate for participating to free-libre biotechnology. First, it is not making money directly on its patents. Second, it may gain highly by improving its technology platform on which it is generating most of its revenues.

Furthermore, it must be kept in mind that free-libre biotechnology focuses on the objective of protecting the freedom of the whole upstream platform of research tools whilst at the same time allowing for the generation of applications. Therefore, only the first stage researches that are essential to the development of applications must remain open. Applications do not need to be free, on the contrary, they will only be undertaken by firms if they are patented and can provide their owners with a competitive advantage. Ativities that are not considered as upstream can be appropriated. So in BIOS, legal control of the application layer is permitted. Or in the HapMap, the patenting of specificities is allowed. A fine balance between 'free' research tool and 'controlled' application must therefore be found and respected.

Free-libre biotechnology is not wishful thinking and has real chance to be adopted in specific contexts. Yet, some questions must still be addressed on the role of patents as instrument to preserve the freedom of technologies. Here are two important points that will have to be clarified in future research:

First, it is likely that there is a threshold in the size of the patent pool above which it is almost certain that the freedom of the entire field will be preserved. Due to the viral property of the licence, once a critical mass will be attained, the choice to agree or not to the licensing terms will then be made obvious. Indeed, as long as the pool is small and other firms can do without using patents that are in the pool, the pool will grow slowly and eventually will never impose itself. But as soon as the pool is big enough so that it cannot or it would be too costly to get around, then firms will have to use patents in the pool and therefore will have to agree on the terms of access of those patents. And the more firms use patents in the pool, the more patents are given back into the pool, thus contributing to increasing it and to reinforcing this size effect. To study this threshold effect, it may therefore be interesting to apply models of increasing return of adoption à la Arthur (1989). Related to this point it is also possible that the quality of the patent may replace the quantity. Even though the pool is small, if it encompasses one patent that is central in the field then it may also grow continuously. This was the case of the BIOS initiative, the success of which was partly due to the fact that the initiator already held one of the most important patents in the field and that many actors needed this patent.

The second central issue deals with drawing the borders between what is a research tool and what is an application. Put it otherwise, between what cannot be appropriated and must be put back into the pool and what can be patented and exploited individually by a firm. This question is central because it will determine the incentives of profit driven organisations to invest in research tools and to participate in free-libre biotechnology. As illustrated by the BIOS case, some things need to be appropriable in order to allow firms to make money. It is hence very delicate to establish the barrier between things that must remain free because they are essential to spur further applications and things that can be appropriable. It is doubtful that there exists a simple rule to draw the border between the two. It is rather likely that this line is different for each situation. But maybe is it possible to find out regular and general patterns that may help to identify this border.

Finally we would like to end this paper with a discussion on the consequences our work may have on “open science”. It is indeed undisputable that patents have now entered the open science fortress and that most universities in the US and in Europe are widely patenting their research (Sampat and Ziedonis, 2001; Stephan, Sumell and Black, 2001; Cesaroni and Piccaluga, 2002; Mazzoleni and Sampat, 2002; Mowery, Nelson, Mowery and Ziedonis, 2002; Carayol and Matt, 2004). Many studies have documented the reasons and the consequences of this trend. Among others, concerns are dealing with the availability of academic research and with the long run dynamics of innovation. Most fears are coming from an aggressive and exclusive use of their patent portfolios by universities. Yet, our work suggests another possible way for universities and public research centres to use their patents. It is possible that patents reconcile incentives to do research and wide diffusion of those researches. The fact that patents can be compatible with a wide dissemination of technologies has been illustrated among others by the Cohen-Boyer patent (NRC, 1997).

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