Open Source adoption outside software industry: identifying key objectives and enablers?

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Résumé :

L'Open Source est apparu dans le monde informatique il y a 25 ans sous le nom de « logiciel libre » et est actuellement utilisé largement pour toutes les infrastructures digitales. Aujourd'hui les entreprises hors informatique s'y intéressent, communiquent sur leur engagement dans cette démarche et explorent la possibilité de mettre en place un Open Source des objets. Les objectifs de cet article sont d'étudier, à travers des entretiens avec des experts, 1) pourquoi les entreprises en informatique et dans d'autres secteurs, plus habituées aux principes d'innovation ouverte, incorporent l'Open Source comme nouvelle méthode de développement d'offre dans des business models ouverts, et 2) quels sont les facilitateurs de réussite de tels changements de stratégie.

La recherche est basée sur des entretiens d'experts : 8 chercheurs académiques, spécialisés en Open Innovation, Open Source, Stratégie et/ ou modèles d'affaires, et 14 managers d'entreprises informatiques ou industrielles, familiers de l'Open Innovation et/ou de l'Open Source. Après avoir positionné l'Open Source Software et l'Open Source Hardware à l'intérieur de l'Open Innovation, l'article identifie les objectifs et facilitateurs clés de l'adoption de l'Open Source.

Les objectifs clés comprennent des aspects opérationnels (réduire les coûts, améliorer sa réputation) et stratégiques (augmenter la taille du marché, dominer ou survivre dans le marché). Nous identifions aussi des dilemmes clés.

Pour structurer les facilitateurs de réussite, nous utilisons le design de Business Model. Les Ressources sont constituées par des communautés de préférence constituées de membres nombreux et actifs sur le long terme. Les Compétences nécessaires incluent le management de ces communautés, ainsi que des connaissances légales et techniques pour être accepté par ces communautés et permettre le travail collaboratif. L'Organisation consiste à commencer par un processus d'Open Innovation puis à passer le relais à une communauté grâce à des produits modulaires et des mécanismes de gouvernance spécifiques. Enfin la proposition de valeur consiste le plus souvent en des stratégies hybrides, basées sur des projets utiles pour attirer des utilisateurs potentiellement contributeurs. L'Open Source Hardware a des problématiques spécifiques (contraintes des matériaux, obligations de sécurité habituelles dans l'industrie).
Nous concluons cet article avec des contributions théoriques et managériales et identifions des perspectives de recherché.

Mots-clés : Open Innovation, Open Source, Modèle d'affaires ouvert, Objectifs, Facilitateurs

Abstract :

Open Source appeared 25 years ago in the software industry and is now widely used by all digital infrastructures. Companies outside Software industry have recently started showing their interest in this subject; they communicate about their engagement in Open Source and have started exploring Open Source Hardware features. The objectives of this articles are 1) to study why companies in software and other industries, more accustomed to Open Innovation and Open business models, incorporate Open Source as a new product and service development methods and 2) to identify the factors to succeed in such strategic changes.
The research is based on expert interviews: 8 Academic Researchers, specialists in the Open Innovation, Open Source, Strategy and/or business Model fields, and 14 Managers, either in software or in industrial companies, practicing Open Innovation or Open Source Strategies. After positioning Open source software and hardware within Open Innovation, the articles identity key objectives and enablers of open source adoption.
Key objectives include operational (reduce costs, improve reputation) and strategic (increase the market, dominate or survive on the market) elements. In this category we also identify key tradeoff.
To structure key enablers, business model framework is used. Resources include communities as a long-term crowd resource; Competencies include Community management and legal and technical competencies to enable the collaborative work and be accepted by communities; Organization include starting with an Open Innovation process, relying on the community to lead the product development process and modularizing activity; and Value Proposal include hybrid strategies and building useful projects to attract users and communities. Specific issues appear for Open Source Hardware (safety and physical-object issues).
We conclude the article with theoretical and managerial contributions and identify research perspectives.

Key-Words: Open Innovation, Open Source, Open Business Models, Objectives, Enablers

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1. INTRODUCTION

Open Source appeared in the Software industry 25 years ago, under the name of “Free Software”. In a movement to react against large companies’ monopoles, R Stallman invented the copyleft License, stating that opening one’s source code would allow people to see this code, to use it, to improve it, under the condition of letting it open, which is also called the “virality clause” (West, 2003). Free Software, which was at the beginning considered a philosophical movement at the beginning, was emphasized a few years later by a more practical and managerial movement, proposing more permissive licenses. After a few years of debates on the differences of these two movements, researchers now focus on the resemblances and agree to study Free and Open Source Licenses as a whole, with the term “Open Source” embracing both Free and Open Source practices (Von Hippel and Von Krog, 2003).

Today, Open Source is widely used for digital infrastructure such as programming languages or databases. Like roads and bridges, these tools become compulsory to use for companies, even if they’re not totally aware of it[1]. In 2002, Tirole and Lerner raised the question about a possible transposition of the Open Source process from software to other industries. Companies (like French bank Société Générale or French car-maker Peugeot) communicate a lot about their commitment towards Open Source practices. There have been recently a few attempts to adapt Open Source Software features to Open Hardware or Open Source Hardware (Bonvoisin, 2017), that is to create an Open Source process for objects.

Open source has been studied a lot in the software literature but management issues about Open Source remain understudied, especially in other industries than software. This article has two aims: 1) analyze the features of these Open Source Software and Hardware phenomena, based on an understanding of opening strategies dilemna (West, 2003; Boudreau, 2010) and open innovation features (Chesbrough, 2003; Chesbrough and Bogers, 2014); 2) understand how companies in other sectors incorporate these new ways of developing

1 http://www.fordfoundation.org/library/reports-and-studies/roads-and-bridges-the-unseen-labor-behind-our-digital-infrastructure/

products in their Open Innovation Business Models (Demil and Lecocq, 2010), and what are the enablers of such strategies.

For this purpose we choose to interview academic and professional experts. Academic experts are specialized in Open Innovation, Open Source strategies and/or Business Models. Professional experts are Innovation or company leaders, either in software or in industrial companies, practicing Open Innovation and/or Open Source strategies.

The next sections of this article are organized as follows: the next section presents theoretical foundations leading to our research question. It is then followed by a description of the methodology and the results of our qualitative study based on 22 expert interviews (academic and managers). The article concludes by acknowledging its limitations and highlighting its contributions to both research and practice.

2. CONCEPTUAL BACKGROUND

Open Source, was at its beginning outside the corporate scope. It was then included in a broader Opening strategy wave inside companies, which led to Open Business models. These are now well established in Software Companies and emerging in other industries, either in their informatics services or in Open Hardware. We are interested in understanding corporate Open Source adoption and enablers. As the Free and Open Source Software movement was at first against “corporate domination”, we found little literature on Open Source and for-profit corporate strategies. Therefore we use literature on corporate opening strategy dilemmas, on Open Innovation and Open business models, and on Open Source software adoption and enablers. With this literature, we want to understand what are the motives pursued by companies when they think about implementing one of these strategies, and what could be corporate Open Source enablers in other sectors than Software and what remains to be studied in this field.

2.1. CORPORATE OPENING STRATEGY DILEMMAS

The reasons for opening a product development have been studied extensively, and can be summed up in three main dilemmas: first, choosing between “adoption” and “appropriability”, second between fostering “diversity” or “control”, and third between opening for “complementary” development or “core” contribution.

The first dilemma that has been considered is the trade-off between “adoption” and “appropriability” (West, 2003): An open strategy might reduce customer fears of being locked in and facilitate innovation adoption. On the other hand, it will lower entry barriers and enable newcomers to appropriate the technology and to compete in the considered sector.

The second dilemma is between “diversity” and “control”. Diversity refers to drawing on external knowledge to facilitate innovation (Chesbrough, 2003). The risks would be a loss in coherence when multiple partners want to innovate simultaneously (Almirall and Casadesus-Masanell, 2010), or of having too few contributors as they would fear the risks of openness and the lack of property rights. Businesses might therefore consider controlling and only partially opening their product development (West, 2003), with a lot of questions to be answered about what to open, which rights to give, which intellectual property to apply, and how to manage the process and the cooperation with entities which may pursue different aims and have different habits in the governance rules, processes and rituals (Von Krogh and Von Hippel, 2006). The third dilemma considers the question “what to open”, either for “complementary” development or for “core” contribution to the product, service or platform. The links with the external partners could have two main objectives: granting independent entities access to complementary products development as Apple does, or, like Linux does, at opening the core platform technology itself so that external partners can improve the platform product (Boudreau, 2010). In other words, there could be an openness of the process or an openness of the innovation outcome (Cheng and Huizingh, 2014; Altamuro, Holland and Hussain, 2015).

2.2. CORPORATE OPENING FEATURES

Open Source is one of multiple forms of opening a product development process. During the early phases of industrialization, British companies have already experienced various forms of collective invention (Allen, 1983; Nuvolari, 2004). In 2003, Chesbrough popularized Open Innovation as a new way of performing innovation, dividing it in two sides: “outside-in activities” to gain knowledge from the external world and “inside-out activities” to find new opportunities for inventions and patents. Among the years, there were various attempts to classify possible methods for Open Innovation strategies. The following table lists various product development opening strategies and how they refer to the opening dilemmas. As pointed out in this table, depending on the aspect Open-Innovation researchers are most

interested in, Open Source is viewed either through its "inside-out" or its "coupled" aspect, but researchers on Open Source Software point out aspects in all categories.

Table 1. Corporate Opening Features

	"OUTSIDE IN"	**"INSIDE OUT"**	**"COUPLED"**	**"HYBRID"**
Open Innova-tion	Scouting, in-licensing IP, university research programs, funding startup companies, collaborating with intermediaries, suppliers, communities, non-disclosure agreements, crowdsourcing, competitions (*Chesbrough and Bogers, 2014*)	Out-licensing, donating IP and technology, spin-outs, incubators, or corporate venture capital, alliances, joint-ventures, (Chesbrough and Bogers,2014); publishing discoveries (Chesbrough and Appleyard, 2007); **Selective Revealing** (Henkel, 2006), **Open Source** (West, 2003)	Mix of outside-in and inside-out processes, strategic alliances, joint ventures, consortia, networks, platforms, eco-systems, (Chesbrough, 2014), **Open Source** (Chesbrough and Bogers, 2014; Sims et Seidel, 2015); Product and process openness (Huizingh, 2014)	Partially open product development (West, 2003; Lerner and Tirole, 2002); Open what is not strategic (Bonaccorsi et al, 2006; Mohiuddin et Su, 2013); Hybrid licenses (Muselli, 2008; Benkeltoum, 2011)
Open Source Softwa re	Adopting Open Source practices within closed-company context (Grand et al, 2004; Lundell et al, 2017)	Contributing to Open Source projects; opening their proprietary products (Grand et al, 2004; Lundell et al, 2017)	Symbiotic relationships with communities about specific projects (Lundell et al, 2017)	Hybrid practices (Grand et al, 2004; Lundell et al, 2017)
Dilem-mas	diversity under control	adoption with appropriability	adoption vs appropriability, diversity vs control	core vs complementary, diversity vs control, adoption vs appropriability

2.3. Is Open Source possible outside software?

Open Source spreads to other sectors via two flows. First flow is that as digitalization of the economy expands, all companies are bound to use more and more software, therefore to use Open Source Software (Schrape, 2017).

The second flow is that Open Source features are general enough to be adapted to other industries and to meet old habits that some industries used to have. It seems that corporate Open Source is a form of collective invention that resists better and lasts longer (Schrape, 2017), which makes it interesting to study its specificities and its potential for generalization. The main feature is that Open Source projects are managed through a "bazaar' mode (Demil et Lecocq, 2006), which represents a new governance structure: open membership, numerous and various kinds of actors and no mandatory long-term commitment, are features that are not exclusive to Software, and could be adopted in sectors where information can be codified and lead to fine-grained modularity.

The success of community-based development has extended to new areas such as pharmaceutical development, space exploration or education (Midha et Palvia, 2012) and Open Hardware communities and business models emerge, who align with Open Source principles (Bonvoisin, 2017; Pearce, 2017).

Open Source Hardware can be defined as Hardware whose design is made publicly available, so that anyone can design, amend, manufacture, and sell the design or product made from it[2]. Bonvoisin (2017) demonstrates that there is a product openness (transparency, replicability and commercial reusability) added to a process openness (accessibility). This concerns all tangible artifacts, whether machines, devices or any physical thing (Aitamurto et al, 2015).

Therefore Open Source features can be transposed elsewhere than Software. Establishing whether the aims and enablers are the same or different remains to be studied. What is expected by companies when adopting Open Source? And what are the enablers?

2.4. WHAT IS EXPECTED BY COMPANIES WHEN ADOPTING OPEN SOURCE?

Corporate participation into Open Source activities was at first considered a way to profit from Open Source by obtaining free-of-charge support from the external community for time-consuming tasks such as testing or debugging (Henkel, 2006). Building on these technical reasons, Henkel et al (2014) added other aims to these technical aspects (facilitating maintenance, complementary products, compatibility; benefiting from the others' code improvements, adding new resources) and identified other reasons: customer pressure and marketing-related benefits (opening new markets, reputation, quality signal).

2 https://www.oshwa.org/definition/

We present main objectives and factors hindering adoption in following table. When articles are about Open Innovation, but study Open Source Software Companies, we choose to present their findings in the Open Source Software column. We divide objectives into two categories: strategic and operational aims.

Table 2. Opening Objectives

Aims	Open Innovation	Open Source Software	Open Source Hardware
Outside-in	**Strategic aims** Expand the pie (Chesbrough, 2003); **Operational aims** Reduce costs and improve property rights (Manceau et al, 2012),	**Strategic aims** Expand the pie (Henkel, 2006) Survive (Benkeltoum, 2017) **Operational aims** Reduce costs (Henkel et al, 2014), Marketing (Benkeltoum, 2017, Kendall et al, 2016)	**Strategic aims** Survive (Pearce, 2017) **Operational aims** Reduce costs (Pearce, 2017),
Inside-out	**Strategic aims** Dominate (Ayerbe et Chanal, 2011), Survive (Van Burgh et al, 2014; Ayerbe et Chanal, 2011)	**Strategic aims** Expand the pie (Henkel et al, 2014) Dominate (Alexy et al, 2013) Survive (Alexy et Georges, 2013, West, 2003) **Operational aims** Improve Reputation, Reduce costs (Henkel et al, 2014)	 **Operational aims** Improve Reputation (Pearce, 2017) Reduce Costs (Pearce, 2017)
Coupled		**Strategic aims** Expand the pie(Benkeltoum, 2017; Kendall et al, 2016; Tesoriere and Balleta, 2017)	**Strategic aims** Expand the pie (Pearce, 2017)
Brakes	Knowledge and collaboration barriers (Bigliardi and Galati, 2016) Organizational and Financial barriers: (Bigliardi and Galati, 2016);	 Organizational barriers (Henkel et al, 2014)	Knowledge barriers (Pearce, 2017) Organizational barriers: (Aitamurto et al, 2015) Market barriers (Lerner et Tirole, 2002;Pearce, 2017) Financial barriers (Lerner etTirole,2002; Pearce, 2017)

Whatever the features “outside-in” or “inside-out” or “coupled”, the objectives and factors hindering adoption are similar for Open Innovation and Open Source. Open Source

Software strategy seems to emphasize the aims, and Open Source Hardware seems to experience the same hindering factors that Open Source Software used to encounter in the 2000s: having to compete with customers and corporate competitors. Coupled objectives are understudied, whether in Open Innovation or in Open Source.

Moreover, to our knowledge, the literature on these subjects does not enable us to understand why a business would choose an open Innovation or Open Source way to develop their product and offers, nor what the relations are between these two strategies. Finally, there is few literature about reasons for adopting Open Source practices outside software industry.

2.5. Open Source project enablers

Open Source let to a new community-based software development process. It implies differences between commercial software projects and Open Source software projects.

Important factors for a commercial software project would be to meet time, budget and functional targets. The success of such a product development can be measured by sales figures and use of such a software (Crowston and al, 2006; Stewart and al, 2006).

On the other hand, for an Open Software project, participation and project activity would be important factors, and the focus is rather on the development than on the use, because it is easier to follow the development of these projects through data-bases such as SourceForge or GitHub. There is a need for a large user base, who can take care of the technical support and provide improvements of the software, beyond the core network of the few developers of the project. This is called a “network effect” (Subramaniam, Sen and Nelson, 2008).

Factors influencing participation are numerous. First developers and non-developers motivations and competences have been largely studied (Bonacorsi, 2003; Stewart, 2006; Alexy and Leitner, 2011…) and stress out the importance of personal reputation. Then, to attract contribution from developers, the project also needs to be popular and to keep a high development activity rhythm at the early stage of the project, to modularize the software, to assign responsibilities to volunteers for bug fixes or software additions (Midha and Palvia, 2012). Last factor influencing participation was the Open Source Type of License (Subramaniam, Sen and Nelson, 2008). The licenses have a balanced impact: Restrictive Licenses would prevent developers from working on the project, but would have a positive

impact on other projects administrators who would rely on such a licensed project to develop their own projects.

To put it in a nutshell, key factors are to attract users and developers to the project. To do this, the authors of the project need to modularize, to assign responsibilities, keep a high development pace at the beginning to gain popularity and make sure that their project is good for the developer's personal reputation. The question is how to do this efficiently?

2.6. Open (Source) business models

When adopting Open Source, organizations tend to reshape their business model. Business models research provides useful concepts to better understand open ways of developing a product.

In 2006, Chesbrough and Appleyard established a link between Open Innovation and Business Models, in the sense that Open Innovation activities are related to a value proposition. Demil and Lecocq (2010) went further in the business model definition, by indicating that Business Models are more than value proposition and value capture, and need to be described with three core components: propositions for value delivery, resources and competences, and organizational structure. These components can be used to describe Open Innovation and Open Source activities. For instance Linux relies on a resource consisting of external partners who are a crowd of committers outside the company (Warnier et al, 2012), which implies a lower cost structure.

In a nutshell, "Open Business model" will refer to business models where at least one part of the resources and organization consists of external entities and networking with these entities. (Demil and Lecocq, 2014). We choose to compare Open Innovation and Open Source enablers, by using the Demil and Lecocq's (2010) Business Model Framework.

Table 3. Open business model key enablers

	Open Innovation	**Open Source Software**	**Open Source Hardware**
Resources	Outside Resource (Chesbrough, 2003) Licenses (Chesbrough, 2003)	Outside numerous resource (Warnier et al, 2012) Specific copyleft protection (Alexy et al, 2013)	Need for and active community (Pearce, 2017) Affordable manufacturing technology (Bonvoisin et al, 2017) Strong branding (Pearce,

			2017)
Competences	Learning effect (Love et al, 2014) concerning the R&D Department (Remon, 2012) or the whole organization (Salter et al, 2014) Management (Davis and Eisenhardt, 2011)	Management, learning effect (Henkel et al, 2014)	
Organizational structure	Rhythm: "Outside-in" before "inside-out" (Lichtenthaler, 2013)	Community network (Grand et al, 2014) Modularity (Alexy et al, 2013)	
Value proposition		Hybrid business models (Benkeltoum, 2011 ; West, 2003; Alexy and al, 2013) Sophisticated customers (Sacks, 2015)	Target technically sophisticated customers first (Pearce, 2017)

Literature shows resemblances and differences between these ways of developing a product or offer. In all case there is a learning effect and a license management, even if the content of these are not the same for Open Innovation or Open Source. The differences are that Open Source addresses more issues concerning value proposition, stressing the need for hybrid business models with sophisticated customers, and that Open Innovation relies on carefully selected resources when Open Source relies on numerous resources. Open Source Hardware has one more difficulty concerning its resources: the need for affordable manufacturing resources.

The literature on Open Source Projects and Open Business models does not enable us to understand really what is at stake when a traditional company decides to change and develop an offer with an Open Source strategy. There is very few literature focusing on what a company needs to change when they want to embrace such a strategy. Describing and analyzing such processes in companies is understudied, and our study aims at contributing to fill this ga We decided to perform a qualitative analysis based on expert interviews in order to understand these relatively new processes.

3. RESEARCH METHODOLOGY

We conducted a qualitative study, based on expert interviews, in order to understand this phenomenon as a whole, and identify potential enablers.

We interviewed 8 Academic Researchers, specialists in the Open Innovation, Open Source, Strategy and/or business Model fields, and 14 Managers, 7 in software and 7 in industrial companies, practicing Open Innovation or Open Source Strategies (see Appendix A and B). For managers, we interviewed large companies, SMES, consortiums, in order to have a high diversity in the respondents. As France is the first European Market for Open Source[3], we interviewed mainly French Experts. The interviews took place from November 2016 to April 2017. All interviews were recorded and transcribed.

Concerning the interview guidelines, we wanted to get insights about the relationships between Open Source and Open Innovation, as the Literature review had shown various relations driven from past case studies, and we also wanted to know more about the present and future. We wanted to know more about industrial companies, about their mindset on these subjects. Last, we wanted to understand if it was possible to identify key adoption and hindering factors for a company which would like to start implementing a product development using an Open Source Way, and what an Open Source way would look like. Altogether, interviews amount to 340 transcript pages (excluding feedback discussions). A few codes were driven from the Literature, and we found other codes by confronting interviews one to each other. We used the RQDA tool for this analysis (Chandra and Shang, 2017; Vitry and Chia, 2016), a qualitative Open Source Data Analyst Tool, based on R[4].

After having analyzed the interviews, we prepared a 13-minute video presentation on the main results and sent it to the interviewed experts, in order to get their feedback on what we had understood, so that they could say what they would agree on and what they would disagree on. We got feedback from 5 Researchers and 7 Managers, which enabled us to get more specific features or examples.

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3 Survey PAC-CXP Novembre 2017 https://www.pac-online.com/open-innovation-it-infrastructure-open-source-insight-analysis-worldwide; cité dans : https://business.lesechos.fr/directions-numeriques/technologie/open-source/030980651430-la-france-championne-d-europe-de-l-open-source-316671.php#Xtor=AD-6000

4 HUANG Ronggui (2016). RQDA: R-based Qualitative Data Analysis. R package version 0.2-8. http://rqda.r-forge.r-project.org/

4. FINDINGS

The qualitative study enabled us to understand the factors deciding or hindering adoption of Open Source for Product and service development processes from a strategic (4.1) and operational (4.2) view. Finally, our qualitative study enabled us to understand what is at stake when a company wants to embrace an Open Source strategy and what the key enablers are (4.3). We sum up our main findings in a summary table (4.4).

4.1. CORPORATE OPEN SOURCE STRATEGIC AND OPERATIONAL AIMS

Strategic aims consist in creating a bigger market and in being a leader on it.

4.1.1. Expand the pie

Making the pie bigger via opening the code in an inside-out perspective is the first aim, it can be achieved through three sub-objectives: starting a new life, improving product continuously and more rapidly and developing new customers' types. Companies hope they could enable some of their products to start a new life thanks to community development.

> *"It is not marketable, I can't go any further to make money out of it, therefore there is no point in having a proprietary right on it, but I can hope that through a collaborative way, it will create value" (a4)*[5].
>
> *Innovation will go at a much higher pace in a network than in a small company that needs to pay their salaries" (m5).*
>
> *"It makes it possible to attract a community much larger around our products, and perhaps, if I earn 10% of what I would have earned before, but my pie has enlarged by 200 or 300 times, I'm still a winner" (a3).*

The second category of strategic objectives aims at market domination.

4.1.2. Dominate or survive on the Market

Open Source principles specify that by opening the code, one allows anyone to see it, improve it and use it for their own purposes, depending on the chosen Licenses. By doing this, companies allow a much quicker dissemination of their products. Some Companies outside Software realized that they had the same dissemination problem for the products or technologies they had imagined in an Open Innovation way, and started to invent some new Licenses, to give a free access to their resources thanks to free licenses based on patents:

5 In following citations, « m » refers to a Manager, and « a » to an Academic Researcher. The numbering is ramdomly done and does not match with the sorting of the table entries in the appendixes.

FRAND Licenses. These licenses give fair rights to use patented technologies in order to give access to new technologies. The result is that, in both cases, companies can freely use infrastructures and build on it.

> *« That is a new trend, it got structured around 2015, and it is really interesting to see the industrial initiatives entwined in these open collaboration layouts, always thanks to licenses and patents, but these licenses have to be more and more accessible, so it is somewhat similar to Open Source, since Open Source is not the lack of rights. (…) Between these famous FRAND licenses and Open Source licenses, we are not light-years apart, we are exactly in the same logic » (a2)*

> *"If Tesla opens, it is because they believe that if they don't enable to spread their technologies, perhaps, their technology won't be the one to be used tomorrow. And Toyota has the same strategy. If their technology leads on 50% of the market instead of 10% of it, they assure technology sustainability, and it is invaluable" (m1).*

As we can see, the dominant logic here is to increase the number of users-customers, to sustain the technology, in order to develop a sector or prevent a competitor from entering the market. This can be done through Open Source, but also through patents opening via free licenses such as FRAND licenses, or through accepting being software piracy.

When companies can't hope to dominate their market, at least they want to remain independent and survive on the market. Using Open Source products can help them for that.

> *« Because if you think about it, if I make a big investment right now in a specific sort of robot, perhaps in terms of having an integration part, by a specific integrator with very specific closed tools, in 10 years from now, I have to revamp my factory and perhaps that system integrator is out of business or perhaps that robot manufacturer is now not competitive anymore. So perhaps I bought 10 robots from a manufacturer A, and I would like to have 5 more robots but from manufacturer B, who now became competitive » (m10).*

4.2. OPERATIONAL AIMS FOR AN OPEN SOURCE PRODUCT DEVELOPMENT

Expert answers point out two main categories: economic concerns and marketing issues.

4.2.1. Reduce costs

The necessity to reduce costs and the impact of Open Source on this challenge are stressed by experts.

> *"For instance, Peugeot is starting to use Open Source, this seems to be clearly because they are in large savings logics, and this is one of the solutions" (a2).*

> *"Let's talk about figures, for instance, if we build a robot, there are at least 2500 software hours, and if I shift to Free or Open Source structures, I divide nearly by three"(m4).*

Companies making the choice of Open Innovation also refer to the economic issue, but rather to make the point that the new technologies are too expensive and too new to be able to hire all necessary and competent people to work on these subjects.

> *"One of the important points is we don't have a choice. Michelin could stay alone when he was manufacturing tires in line with his own technological competence. When you start getting into technologies that aren't part of our core businesses, like biomaterials or digital technologies, you can't hope to have all the necessary skills in your team. It is necessary to create partnerships, you can't reinvent yourself from the inside continuously" (m9).*

The second operational aim is to use Open Source as an active marketing tool.

4.2.2. Improve the reputation

Experts point out numerous marketing issues, first to meet customers' requirements, but also to shine to attract resources and to develop a quality image. The first marketing reason is to meet customer requirements.

> *"Some user clients specifically ask for the use of Open Source codes so that they don't need to pay for the intellectual property. We have a project with the Airbus group, so not so small, and another project with the PSA group, where the technical teams expressly say: we want your codes to be modifiable by our teams, so we ask that you develop with ROS-industrial (Robotics Operating System). While we developed our codes in the machines or in supervising in a somewhat proprietary way, in C++, we tried to make it illegible for our clients, well you see what I mean, now we have people saying : well, we want to open"(m4)*

The second factor is that opening the product development process is good for the image and reputation. It doesn't need to be Open Source, and Open Innovation has also a highly positive impact and nearly being compulsory for image and reputation.

> *"I think, that in terms of communication, if you say that you are opening your process, whatever it is, either Open Innovation or Open Source, or crowdsourcing, it's always appreciated. The boomerang is that if you don't communicate about your openness, it's as if you were practicing closed innovation (...) It is corporate to say "we do Open Innovation", because if you don't say it, you're not a cool company, or you won't be attractive to customers or future workforce"(a7)*

This marketing advantage is nuanced by a few experts, mainly from the Free Software Movement, who stress the very technical spirit of some communities, and their lack of communication skills.

> *"Most of them are technicians, and technicians are not interested in business, in marketing, they're bored by these subjects. Therefore, there may be communities, who are very good on a technical point of view, who are solving problems, but we have no communication skills, and are being ignored, this is not too much a problem, but further, there are decisions that are made against them simply because they didn't communicate. This is very often the case with free software" (m8).*

In fact, when a customer buys an open product, he buys a transparent and evolving product, whereas when he buys a proprietary product, he buys a stable quality product.

> *"When we buy a Microsoft product, we know we buy a quality product, (...), I should say, when we buy a Microsoft product, we know we buy a product at a stable quality level" (a3).*

Industrial experts stressed out that, more than quality, the big issue is to be able to determine who is responsible, and to manage risks.

> *"Ok, let's imagine, you enter a car, your car is a bit automatic, for instance brakes are automatic, or there is an ABS system for instance. Ok, ABS is an open code, at least 500, 600 developers have participated to it. There comes an accident, the code is open. Who is responsible? (...) On Rotterdam site, there was a fatality, one or two years ago. The developer told me: if I program the validation code for the machine, perhaps one day someone will come and make me accountable for a bug in my program? So, this is the limit for us, in the industry, of Open Source. In Industry, we were talking about products/services, we sell more and more services. In fact, Danone, Pfizer, as they know nothing about technical matters, they buy us KPIs. In general, they buy, the robots we're selling them, production pace. (...) If you've a bug, let's imagine you stop a plant for 3 hours, it's just impossible to consider it" (m4).*

4.3. CORPORATE OPEN SOURCE BUSINESS MODEL ENABLERS

Corporate Open Source enablers consist in creating and managing communities as a new resource, build and grow new managerial and technical competencies, and finally organize differently to be able to work suitably with communities and reinvent value proposition.

The first enabler is to create and manage a new resource consisting in one or several communities**.** Concerning Open Innovation, the Resources were clearly the Property Rights, as well as the physical assets created and/or owned by the company, and the heterogeneous network of carefully chosen partners (in an industrial sector) or the crowd (in a more BtoC sector, as contributing customers). This crowd resource is even more important in an Open Source product development, because you want to rely on it on a long-term basis, you want committers to be numerous and active, and therefore you need to implement new management rules and be careful to be ethical and fair.

> *«If we examine GitHub contribution system, which is a reference for the last few years, there is a project about to launch, and if we realize there is an improvement to make, in the end, we carry out the changes on our part, we call what we call a pull request, that is, I suggest my changes, so there is someone who will carry out a review, who will examine if it is in agreement with its expectations, if the quality of the code is in good enough, if it is not going to break it all, that's it, a lot of controls, and he is in charge of the decision whether or not to fuse the code and integrate the request. This is not a new process since Linux is also based on this since decades » (m2).*

The second enabler consists in reinventing Value Proposition towards hybrid solutions and useful projects. From the Literature, the hybrid strategy had emerged, and the respondents confirmed it as being one of the main effective solutions for running a business related to Open Source product Development.

> *«Concerning the Renault POM platform, the Twizy that has been a little bit ripped apart and a little bit more Open Sourced, in any case where a part is intended to be an Open Source component, the question will need to be discussed: do we keep it closed for safety reasons, business, and intellectual property? And what do we need to open exactly or what do we need more than open actually? We have to open and document to give tools to people to build on, which means we reach exactly the patterns of a SKD in the software world. If we create a platform for people to develop on, we don't just need to create a platform, we also need to give them a development environment, we also need to give them documentation, we also need to give them whatever is necessary to design above, it shouldn't be a capacity wall so every time they need a drawing, a dimension, any interface with the software, they don't have to look for 10 months » (m11)*

What is new is the need for having a useful project, in the sense of a project useful to a group of people, if company wants to attract a community big enough to provide a quick enough rhythm of improvements.

The third enabler consists in building and growing new competencies: mindset, community management, legal and technical knowledge, in order to get integrated in or run communities. The mindset is very important, and the Community management is also a new skill to acquire. Same as for Open Innovation, the learning effect and the management aspects are important, but in fact they refer to a different content.

> *« In the innovation communities, there is what I like to call « sweat equity »: you have a stake in the community, your weight in the decision process (…) is based on how active you are as a contributor, how helpful your suggestions are within commons discussions (…). Typically the Open Source are more based on sweat equity, it's not a matter of putting money and asking for things to be done, it's a matter of becoming part of the community, showing that you have some skills in the game or you have some interest in it because it is important for your business because you're willing to support it also maybe for part of the development, which are not benefiting directly your business, but they are good for the initiative to be done anyway. » (m10)*

On top of that, companies will need to gain more legal knowledge and to be more skilled on technical aspects, if they want to be accepted by the community.

There are specific difficulties related to Open Source Hardware: the security obligations, and the difficulty to take a step forward from design to real object.

> *« There are a lot of security issues, (…) and with Open Source it is more difficult to master the risks. "Business continuity" is very important, in a business you need to have control over the risks » (m9)*

> *« It is the transition from the virtual object to the physical object that is going to be a problem. Certainly people will be able to collaborate on the virtual object. But within all the contributors, how many will cross the line from virtual object to physical object? And we know that when we go from virtual to physical object, there always are problems that we stumble upon » (a8).*

Last enabler is about Organization: Modularize activities, cooperative and ethical relations with communities. This means a new organization concerning your products design, and also your internal management. Concerning your products design, you need to modularize activities as much as possible, so that distant people can deal with separate parts, and take one part in charge. As far as internal management is concerned, companies need to adapt their work contracts in order to enable their salaries to work with communities. It means that the manager won't necessarily be the one who tells his subordinates what to work on, he has to let them work in the communities, along with the community agenda.

> *«To us, it is not being a member of our Consortium that changes the company, but rather the decision to use Open Source software: they need to enable the developers to work with Open Source software, they need to change the work contracts, and they perhaps need to prepare the developers (…). For example, the Linux kernel, 92 or 95% of the developers are not individual developers working at night, they are people that work for a company, and their boss says « go there work for the Open source software for us ». Most of the Open source developers in the world are developers that work for a company like any other developer, except that they don't work for their company but work together with the other developers in the world with which they form a community » (m7).*

As we can see, Corporate Open Source Business model is specific, especially as regards to Competences and Organization.

4.4. Main results of the analysis

As a synthesis of our findings we list in the following table key differences between Open Innovation and Open Source, regarding key objectives and key enablers.

Table 4: Key definitions and objectives

	Open Innovation	**Open Source Software (OSS)**	**Open (Source) Hardware**
Definition	Half-open; Companies leads the path, property rights	Open; Rely on community for product development, collaborative working "Use it at your own risk"	Open Source applied to objects: Open Design Open Making

Open Innovation and Open Source both towards open access for infrastructure technologies			
Strategic objectives	**Compulsory** to enter new technologies and digitalization	**Expand the pie** (new life through community) **Dominate or survive**	Idem OSS
Operational objectives	**Reduce Costs** **Improve reputation** (shine, attract young and talented workforce	**Reduce Costs** **Improve reputation** (shine, attract young and talented workforce)	Idem OSS
Trade-offs	Secret/ innovation and motivation	Secret/ innovation and motivation Shining/ losing workforce	Idem OSS +"Use at your own risk"/ risk control obligations
Obstacles	Different corporate legal habits from the partners involved, different cultures from each partners	Hacking image, technical spirit of free communities,	Going from plans to reality, documentation publishing, Risks, Bug-fixing, after-sales ameliorations?

Table 5: Key enablers

	Open Innovation	**Open Source Software (OSS)**	**Open (Source) Hardware**
Resources	BtoB: carefully chosen partners, BtoC: crowdsource	Long-term crowd resource, distance and asynchronous work, mixing very skilled and simple users	Idem OSS
Competencies	Mindset, Product development, Legal knowledge to secure the result	Mindset, Community management (management rules, ethics, nurturing methods, sweat equity), Legal knowledge to enable the collaborative work and capture value, Technical knowledge, to be accepted in community	Idem OSS + Security management,
Organization	Lead the process	Open innovation first, Rely on the community to lead the process, Modularize activity	Idem OSS + Affordable manufacturing technology
Value proposal	Property Rights, open licenses on patents	Hybrid solutions Useful projects, to attract users and build community	Idem OSS

5. CONCLUSIONS

Our aims were to understand how the Open Source model born in Software industry can be transposed to other industries, and how it can be compared to the Open Innovation methods, as most industrial managers today refer to this product or service development strategy and method. We wanted to know if the objectives are the same and if the key enablers are the same. To succeed in this task, we needed to make sure of the definitions to better understand main resemblances and differences between these open product and service development methods.

Concerning objective, choosing an Open Source development strategy is like choosing an Open Innovation strategy. The reasons for Open Source development are more strategic than Open Innovation. But these two ways of developing an offer are getting nearer to each other. Managers outside software and considering Open Source methods are concerned by juridical matters and by the loss of their competitive advantage due to opening. In fact Open Source Software companies consider Open Source in a much more offensive and proactive way than what is believed outside this sector, to gain new markets and stay independent.

Concerning Open Source Hardware, (limited to Open Design), issues are similar to Open Source Software. But, when it comes to producing and selling, Open Source Hardware seems to lead to more difficult questions because of the responsibilities in risks taking. If the car goes wrong, the car-maker is responsible, which is different from the Open Source philosophy “use it at your own risk”. More investigation should be done on this subject, to understand the quality insurance process in Open Source Software and how it could be implemented in other industries.

As far as the enablers to succeed in Open Source Strategies are concerned, choosing Open Innovation first implies for companies to determine the best-fitting property rights and how they will secure the results of their joined innovation. Therefore this is more difficult than closed innovation because the partnership has to combine different corporate legal habits from the various involved partners. Secondly, this way of developing a product or service is launched by a company that expects exclusive advantages out of it.

Choosing Open Source is a whole other matter. Companies outside software and considering Open Source as a new way of product development believe at first that it is a more complicated way of developing a product or a service. They need an Open Innovation effort at the beginning, to create their community, and they need to learn about numerous

Open Source juridical licenses to choose the most appropriate one to release their code and still manage to capture some value. But then they realize that Open Source is much more than releasing their code: it is a very elaborate way of working cooperatively. Therefore they need to nurture their community, so that they benefit from their involvement and their product improvement propositions.

Managers in industrial sectors are preoccupied by the juridical matters, but in fact the most critical thing is the community empowering, and the fact that the company's influence will depend on their commitment to the community, and not on the money they put on a contract, like in a R&D purchase or in an "Open Innovation contract". Moreover, they have to accept that this external resource will lead the way, contrary to Open Innovation where the company is deciding where to go. In this respect, Crowdsourcing is very different from Open Source.

Concerning Open Source Hardware, as far as it is limited to Open Design, issues are similar to Open Source Software. But, when it comes to producing, Open Source Hardware seems to lead to more difficult questions. After the responsibilities in risks taking, there are also difficulties with going from plans to reality, depending on materials behavior. Leaving the Open Source Hardware to design aspects is easier because it doesn't struggle with capitalistic matters such as machines and plants. It is yet unclear whether 3D-printing will facilitate the change of state and whether Fab-Labs and Makerspaces will change the way things are produced. The last challenge is after-sales ameliorations and bugs-fixing. For software, updating a product is easily done through plugging-in, but how can an individual manage to update easily physical parts?

As a result of all this, does Open Source product development implies a more complicate or different process for companies? In any case, the juridical aspect is tricky, whether companies want to go for Open Innovation or for Open Source. Open Source Licenses seem to have had an influence on other industries: Some car companies have started to "open" their licenses, and "FRAND" Licenses were created to authorize Fair, Reasonable and non-discriminatory use of structuring technologies. In other sectors, Companies settle patents pool for the same purpose. Then, as we've mentioned previously, the main issue is not juridical matters but collaborative working. Going for Open Source product development forces a company to go from product development to community management with ethics. This requires managerial skills in order to run a number of exterior and perhaps ordinary

using and committing resources, and accept these resources to lead the way. From this aspect, we could say that Open Source is more difficult to run than Open Innovation.

So, between Open Source Software and Open Innovation, the nature of the difficulties is different, and it is still unclear whether the level is different or not. Nevertheless, what is sure, is that there are levels in involvement in Open Source practices as there are levels in Open Innovation practices, and that the classification (Outside in, Inside out and Coupled) proposed by Chesbrough (2003, 2014) is valid for these two ways of developing an offer.

Research output: characterize Open Source integration in corporate Open Innovation strategies. This qualitative study enabled us to understand why companies are now considering Open Source as one of the corporate Open Innovation Strategies, and what factor hinder this adoption. We understood that this integration requires new skills and a new ethics approach towards the communities they cooperate with.

Managerial output: give keys to managers, to understand that Open Source is more than releasing code. From a managerial point of view, our research helps managers to understand that Open Source is much more than only opening their Source Code or their secret recipes and therefore wasting their competitive advantage. The reasons for opening one source code are more numerous than cost savings, and might explain why Open Source is today the dominant feature in the Software industry. As for Open Source hardware, hindering factors are strong, the question of the responsibility is clearly to be tackled by companies who want to enter these markets and convince their customers. Then, only opening in an inside-out direction means wasting a competitive advantage, but companies will regain this competitive advantage by managing to grow a strong and active community and re-visiting their business model

6. LIMITATIONS AND FUTURE RESEARCH

Our study encounters a few limits. Our expert sample do not include experts from the United States, although this country is known as the first market for Open Source. Moreover, our study is quite centered on industrial and BtoB activities, and not in services or BtoC companies, although these sectors. Services have started investigating numerous ways of co-working with their customers, and it could be possible that they have things to teach to Open

Source Software companies. Moreover our study on adoption centered on determinants for adoption, but determinants for closure could be also interesting to study.

Finally it would be important to measure the importance of this phenomenon and its consequences on corporate performance, in order to deeply understand the real effect of opening on the capture of value, as this is what many managers are most worried about. For instance, opening the platform so far as to give right to modify core components seems less profitable than opening for future additive components (Boudreau, 2010). It would be interesting to have a global overview on the subject, to extend the study of Cheng and Huizingh (2014) on the effect of Open Innovation on corporate performance.

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Annexes

Appendix A. Research Experts in Management

C. Ayerbe	Full Professor, Nice-S-Antipolis	Innovation Management and Property Rights
J-C Boldrini	Associate Professor, Nantes	Strategy, Open Innovation
B. Demil	Full Professor, IAE Lille	Open Source, Open business models
X. Lecocq	Full Professor, IAE Lille	Open Source, Business models
A. Tellier	Full Professor, Caen	Open Source, Open Innovation
N. Benkeltoum	Associate Professor, Centrale Lille	Thesis “Manage and understand Open Source”
T. Letexier	Associate Professor, Rennes University	Thesis “Open Source role on industrial activities shaping”
L. Muselli	Associate Professor, Telecom Paris Tech	Thesis “Open Source as a strategic tool”

Appendix B. Managers experts – Businesses and consortiums

G. Becue	General Manager	SMILE (Open Source Software integration and management)
M. Bordignon	Consortium General Manager	ROS-Industrial, (Robotics) Germany
S. Fermigier	Founder - CEO	Abilian (Open Source application platform vendor)
C. Emde	Consortium General Manager	OSADL (automation Software), Germany
M. Launay	Founder - CEO	Ecreall (Free Software services)
S. Meriot	Security Software Engineer	OVH (Hosting with Open Source)
P. Montarges J. Rivalan	Founder R&D Manager	Alter Way (Open Source Web platforms specialists)
T. Baschet	Head of Business Unit	Zehnder Group (Heaters)
M. Portigliatti	Scientific Director	Michelin (Tires)
L. Unger	Open Lab Paris Director	Renault (Mobility solutions)
G. Caverot	Innovation and Robotics Manager	BA Systèmes (Robotics)
A. Sanguinetti	Robotics Engineer	Deepsky Corp (Visualisation)
M. Bauwens	Founder - peer-to-peer expert	Foundation P2P Alternatives
V. Roger	Corporate Business Development	CEA, Optics and Photonics Division

NB: The experts answers represent only their own opinions.