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Enabling and sustaining collaborative innovation

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Abstract

This paper extends the principles of open source software development to a non-industry-specific level by introducing the Open Source Innovation (OSI) model. OSI exhibits main differences to other related models and concepts such as the private-collective model, commons-based peer production, R&D networks and is therefore an innovation model in its own right. In order for OSI projects to be successful, numerous factors need to be fulfilled. We make the distinction between four categories of factors: economic, technical, legal, and social. In each category, we differentiate between enabling and sustaining factors. The enabling factors must be met at the beginning of the project, whereas the sustaining factors must be satisfied as the project progresses.

1. Introduction

The proliferation of the Internet combined with the advent of Web 2.0 has opened up huge opportunities to users worldwide. The evolution of the Internet into an interactive, user-centred network of websites and applications allows individuals to build a global digital forum for their ideas, to upload and share content, to communicate, and to co-develop content with other users (Janzik 2007). With these evolving technological possibilities, the Internet provides platforms for an increasing number of user-initiated or user-centred innovation projects (Anderson 2007). With its wide reach, low transaction costs, and the great variety of shareable information formats, it enables co-operative projects which were hardly conceivable some years ago (Tuomi 2002).

The success of open source software (OSS) development projects is a case in point (Comino et al. 2007). Vendors of proprietary software solutions have had to observe open-source solutions taking root and occasionally even taking the lead over proprietary products in many market segments (Benussi 2006). A total of 170.000 OSS projects are registered on the Sourceforge database (Sourceforge 2008). Linux alone has more than 29 million users (Linux 2008). In short: „The viability of the open source mode of software development is not in question. It exists and works" (Baldwin/Clark 2003, p. 3).

This success of OSS projects has attracted much attention from the scientific research community over the last years. OSS was identified as an example of a "new innovation model" beyond markets, hierarchies and strategic alliances (Osterloh/Rota 2007), that has also been called the "community-based model" (Shah 2005) or the "open source method" (Osterloh/Rota 2007). Despite the assumption that other industries may also witness open source development processes in the future (Lerner/Tirole 2004; Maurer/Scotchmer 2006) and even some observations of existing projects (e.g. Shah 2005), the main body of research has analysed the software industry itself. Our paper focuses on the question under which conditions joint development projects built from voluntary contributions can take place in industries beyond software. We will find that Internet-based enabling platforms play a prominent role in this context.

Based on a short review of the literature in the next section, section 3 defines the concept of Open Source Innovation (OSI) as a generalisation of the OSS model and relates it to existing models of collective invention or development. In section 4, we systematise the factors that enable and sustain OSI in industry practice, drawing both on previous research on OSS and some case examples from different industries. Finally, section 5 summarises the principal results of the paper and proposes directions for future research.

2. The Open Source Software Model of Innovation and the Internet

According to von Hippel (2003, p. 1151), "software can be termed open source independent of how or by whom it has been developed: The term denotes only the type of license under which it is made available." Unrestricted access, utilisation, modification and redistribution of source code constitute the characteristics of OSS (Bonaccorsi/Rossi 2003). They not only "keep the code in the commons" (Kogut/Metiu 2001, p. 257), but also support the continued motivation of users to contribute to the project by precluding the appropriation of the created code by one single actor (Franck/Jungwirth 2003).

At the same time, OSS projects feature „typical open source development practices“ (von Hippel 2003, p. 1151); "general characteristics" and "structural conditions of successful OSS projects" (Hertel/Niedner et al. 2003, p. 1161) have been identified as well as constituent OSS "ingredients" (Lerner/Tirole 2004). The assumption that the OSS model may be transferable to other industries usually refers not only to the fundamental licence conditions, but also to these practices and "ingredients" (e.g. von Hippel 2003).

Four groups of characteristics have been analysed in the literature: (1) the actors and their motivations, (2) the conditions of contributing, (3) information sharing and the innovation process, and (4) project governance and organisation. This partition builds on the trisection proposed by von Krogh/von Hippel (2006). However, we try to add granularity in their second area, termed project governance, organisation and the innovation process, while their third area, the competitive effects of OSS, is not the focus of this work.

(1) In relation to the actors of OSS, it has been shown that both single individuals and companies contribute to projects, with approx. 30% of the programmers involved being paid by companies to co-write code. These programmers contribute approx. 50% of all lines of code, mostly with full knowledge of their supervisors (Lakhani/Wolf 2002). The range of motives that stimulate contributors to participate in software development has been a core issue for researchers. Rent-seeking and donating behaviour co-exist, without one crowding-out the other (e.g. Franck/Jungwirth 2003). Free-riding behaviour is curbed by the selective accrual of the benefits of contributing, thus making code contribution self-rewarding (von Hippel/von Krogh 2006).

(2) In general, participation in OSS projects is open to individuals or companies with sufficient programming expertise. However, not every interested party is necessarily granted access to the developer community. Their acceptance is more likely when they behave according to the "joining script", a mostly non-codified progression of effort and behavioural patterns (von Krogh/Spaeth et al. 2003). In some projects, the community even sets more stringent access rules that exclude some potential contributors, as examples from the computer games industry illustrate. Once accepted, participants can choose to volunteer effort based entirely on their own preferences, i.e. without being subjected to any form of coercion (e.g. Baldwin/Clark 2003).

(3) As discussed above, the conditions of free code sharing, modification and re-distribution are constituent characteristics of OSS development processes. Programmers share their code out of an expectation of reciprocity (Maurer/Scotchmer 2006) or a feeling of reciprocal obligation (Shah 2006) within a system of network-generalised exchange (Ekeh 1974). The utility expected in return is frequently incommensurable (Lakhani/Wolf 2002). Access to

results is not restricted to any particular group, allowing free-riders to profit from results without recompense or reciprocal effort (Osterloh/Rota 2007).

(4) From a technical perspective, collaborative development requires two fundamental conditions. First, a modular code architecture is necessary to keep individual contributions manageable in terms of required effort and expertise (e.g. Baldwin/Clark 2006). Second, low-cost communication tools and platforms are needed to support the development process (Hertel et al. 2003).

Project organisation and governance exhibit complex patterns that are still being researched (von Krogh/von Hippel 2006). Self-organisation has been found to be crucial, with programmers selecting their tasks themselves and ensuring that their work runs well within the latest release of the software (Bonaccorsi/Rossi 2003). Self-governance likewise plays a prominent role because autonomy helps to keep up intrinsic motivation (Deci/Ryan 2000). Peer-review serves as a means of quality assurance (Johnson 2006). The group itself ensures that its code of conduct, be it explicit or tacit, is observed by all contributors (Osterloh/Rota 2007).

Due to their reliance on communication, the sharing of results (3) and the coordination of project-related effort (4) are highly dependent on Internet platforms (Kollock 1998). IT solutions are crucial when OSS projects involve programmers within a community or an innovation network that sustains interpersonal ties (Wellman/Boase et al. 2002, p. 4).

3. Taking OS Beyond Software

The discussion on transferring OSS to other industries needs answering many questions: Which aspects are to be transferred? How can software-specific conditions be relaxed? Which additional factors need to be taken into account? In fact, a direct transplantation of the OSS model to industries may not be feasible due to specific surrounding conditions in the software industry. As a generalisation of the OSS model, we propose the broader concept of Open Source Innovation (OSI) that incorporates the OSS model. We define OSI as an innovation generated through volunteer contributions. It is characterised by a non-market transfer of knowledge between the actors involved in invention and those involved in exploitation. Actors involved in invention provide open access to their results and allow unrestricted utilisation, modification, and re-distribution.

Wikipedia is the most-cited, but not the only example of OSI. Other instances of the application of the OSI model of innovation can be witnessed in the automotive industry (e.g. the OSCar project), in pharma and biotech (e.g. projects coming under the BiOS licence, see Pearce/Ferguson 2006), in architecture (e.g. the OSAFA project), and in sports equipment (Franke/Shah 2003).

Our model builds upon and overlaps with many of the collective innovation models proposed in the literature. The “private-collective model” (von Hippel 2003) lays the theoretical groundwork for OSI. In OSI projects, private resources are spent in order to contribute to the production of a public good. However, OSI is the result of a *collaborative* development process, a characteristic that is encompassed, but not required by the private-collective model. Furthermore, the exploitation of the results is not focus of the private-collective model, whereas it is a defining characteristic of OSI.

The private-collective model also covers instances of collective invention, which describes “the free exchange of information about new techniques and plant designs among firms in an industry” (Allen 1983, p. 2). Collective invention is usually observable when technological uncertainty is high and a social network of experimenters share their ideas without the restriction of intellectual property rights. Once the technology leaves the exploratory phase, profit-seeking behaviour tends to bring information sharing to an end (Meyer 2003). OSI, by

contrast, is a broader concept, as it includes invention and exploitation and is not restricted to commercial contributors.
Benkler (2006) describes OSS development as an instance of „commons-based peer production“. Peer production refers to „production systems that depend on individual action that is self-selected and decentralized, rather than hierarchically assigned” (p. 62). The term commons-based underscores that peer production rests on “inputs and outputs of the process [being] shared, freely or conditionally, in an institutional form that leaves them equally available for all to use as they choose at their individual discretion” (p. 62) OSI and commons-based peer production overlap to a large degree. However, OSI is both a broader and a more stringent concept. It is broader because it allows some hierarchical element of coordination. And it is more stringent since peer-production allows some restrictions on sharing, particularly “limited-access common resources” where access is limited to a well-defined number of actors.
Finally, OSI should be compared to R&D networks established by companies (e.g. Miotti/Sachwald 2003), to user innovation networks (von Hippel, 2002), and to the community-based model of innovation (Shah 2005). OSI can be generated by commercial or private contributors or a mixture of both groups, in distinction to R&D networks. If commercial companies participate in OSI, they may profit from using the product developed in the OSI process but may also have different objectives (see section 4). The community-based model, by contrast, is based on “open, voluntary, and collaborative efforts of *users*” (p. 1), meaning private or commercial, but still user-innovators. The same restriction is inherent in user innovation networks. The free sharing of results with the public is a defining characteristic of OSI, while it is not common with R&D networks where results are proprietary to the organisations involved. Moreover, OSI relates to exploitable innovative products and processes. This is not necessarily the case in user networks.

4. Enabling and Sustaining Factors of OSI

Having defined the OSI model, we need to analyse the factors that promote its success. These factors have been so far neglected by the literature. However, they should be examined, as they point to reasons why certain projects are more successful than others, and why some open source projects fail. Our examination distinguishes between **enabling** and **sustaining** factors. Enabling factors are conditions that are prerequisite for starting OSI projects. If these fundamental factors are not satisfied, the project is likely to fail; they represent necessary but not sufficient conditions. In order for the project to be successful, sustaining factors should be met and maintained over time.

Economic Factors

An OSI project may be initiated by a group of actors, be they individuals, organizations or a mixture of both. Although not required by definition, they may often be product users. With regard to user innovation, von Hippel (2005, p. 95) notes that “users will find it cheaper to innovate when manufacturers’ economies of scale with respect to product development are more than offset by the greater scope of innovation assets held by the collectivity of individual users.” In other words, a user-driven OSI project is likely to emerge when product development resources at the disposal of users are superior to the resources a firm can supply with respect to the innovation task. Such a project has the added benefit of distributing the risk of failure over many actors, in contrast to proprietary projects, in which risks are carried by only a single or a few organizations.
In general, actors (individuals or organisations) will participate in open source projects, if their perceived benefits more than outweigh the costs of contributing. Particularly with individual actors, the benefits and costs are not necessarily monetary. Many intrinsic and

extrinsic factors drive developers to continue making contributions, even in the presence of free riders, who profit from the work of others without reciprocating effort.

For commercial contributors, by contrast, the participation in OSI projects is appealing if it increases profit or promotes the attainment of other strategic goals. E.g., they may engage in OSI projects to benefit from the positive effects of standardization. An “innovation that is freely revealed and adopted by others can quickly become ‘a dominant design’ or even an ‘open standard’ that may pre-empt the development and/or commercialization of other versions of the innovation” (von Hippel/von Krogh 2006, p. 301). Needless to say, a firm achieves higher economic benefits when its technology becomes a standard. Similarly, firms may profit from OSI projects when they gain well-qualified external support for their own development efforts, or as they may be able to raise customer demand for their own products if they are complementary to the project outcome.

Recapitulating, an important requirement that must be fulfilled before starting an OSI project is that individuals and organisations perceive a positive economic surplus. Only in this way does the OSI project have a strong and stable economic ground. This enabling economic factor must be complemented with sustaining factors over time.

Among these factors, economical production and distribution processes are especially important. In the case of software, the costs of production and distribution are low because the code is a piece of information that can be spread over the Internet. With OSI, costs, especially production costs, can well be higher. Many examples show that single persons bear the costs of making prototypes when the product is relatively simple (skateboards, kite surfing). But when the products are complex and production requires large investments, it is unlikely that the developers working on the project shoulder the costs. In this case, the developers themselves or the project coordinator (if there is any) must find the financial means to support the project. For instance, developers may convince an industrial company or a research institution to support the task of making the prototype (Lettl/Herstatt et al. 2006).

Another important sustaining factor promoting the success of OSI projects is the realisation of positive network effects. Network effects can lead to accelerated development processes and higher product quality. With more people working on the project, mistakes in product design can be more quickly discovered and then mitigated.

Technical Factors

From a technical perspective, a basic product design must be available at the inception of OSI projects. In open source software, this is called the kernel. “The kernel of an operating system is the base layer of instructions that control the key information processing and resource allocation functions that make a computer function” (Weber 2004, p. 99). For physical products, the basic design is the set of preliminary design concepts, represented by the blueprints, which are freely revealed for further development. The basic design is necessary during the initiation of the project, as it provides the framework, which shapes design efforts. Technically, the Internet often represents an important condition for starting OSI projects (Raymond 2001). Before its wide diffusion, people who contributed to OSS projects had to exchange their concepts using copied materials and hardware. Since charging distribution fees was prohibited at that time, developers themselves had to bear the copying costs, an inconvenience that inhibited software diffusion (Weber 2004, p. 100). With mass access to the Internet, however, information distribution became very cheap; ideas and concepts can be exchanged at almost no cost. In the case of software products, the code (and thus the product itself) can be distributed online. While this is impossible for physical products, it should be noted that the output of physical product development in its first stages is nothing but information (von Hippel 2005). Thus the Internet can support innovations related to the development of physical products as well. In addition, it represents the platform, on which online toolkits run. Toolkits enable one to administrate project memberships, while offering a set of tools to enhance creativity and make it easier to communicate between the participants. The transfer of the open source concept – as practiced in software programming – to physical products is not without difficulties. To run, test, and debug a software application, developers need only a computer and a compiler. In the case of physical products, however, matters are different; building and testing product prototypes can be costly. Since the production of real prototypes is cost-intensive, online toolkits for OSI can offer simulation and virtual testing facilities.

OSI projects can be initiated for products with high level of structural and technological complexity (Bessen 2005). Consequently, product development is not easy to manage. The resulting difficulties are overcome only if the whole task is divided into smaller, manageable, and independent sub-processes. In so doing, each developer can work independently on a portion of the development process. The integration of the sub-solutions ensures the coherence of the whole product design. Process modularity in development is therefore, a very fundamental requirement for starting an OSI project. Note that we do not call for product modularity, which is a more stringent requirement. Product modularity implies that the development process is modular, but the reverse is not true, as a development process may be decomposable into small manageable sub-processes in spite of a non-modular (integral) product. To illustrate, pharmaceuticals are integral in nature, but their development is achieved in a modular way.

In addition to these enabling technical factors, a set of sustaining factors should be satisfied. First, easy communication must be ensured over time. In other words, every project participant should be able to communicate with every other participant in the network of developers to exchange ideas. It should be noted, however, that it is unlikely that every node in the network communicates with every other node. Due to the modularity of the development process, developers working on the same part of the project will tend to communicate more intensively. Second, because the number of developers is expected to be increasing over time, the technical solution that supports communication must be able to accommodate a larger number of participants. Third, all participants should have easy access to the means or tools that are necessary to create and modify product designs. Finally, an important aspect is documentation. The advantages of an OSI project cannot be realised, unless each member can build upon the ideas of the others. Similar to open source software projects, the works that are freely released have to be sufficiently documented, so that the developers in the network can easily understand the blueprints of their peers. Standard templates, which specify how to archive design-related information, can support documentation.

Legal Factors

In addition to the economic and technical aspects, the legal factors enabling and sustaining OSI need to be analysed. Many experts attributee a large fraction of the success of OSS to the creation of tailored licensing conditions (Osterloh/Rota 2007). Outside the field of software, there are also licences that support OSI projects, e.g. in the case of the Simputer hand-held or the Biobricks project. The Creative Commons and several other licences referring to so-called open content are neither project nor industry-specific (Liang 2004).

Licenses specify the appropriation conditions of innovative results; they also can be shaped to ensure a collective ownership of results (Benussi 2006). Osterloh/Rota (2007, p. 166) stress that "…people do not contribute to public goods if no rules exist preventing them from being exploited by others." Similarly, empirical studies find that people are more willing to contribute to public goods when others contribute as well (Frey/Meier 2004). Besides assuring contributors that their donating behaviour will not be exploited, licences serve to

"induce compliance with the philosophy expressed in these licences […] they protect the generalized reciprocity that characterises community culture" (Kogut/Metiu 2001, p. 257).
In addition, licences need to address the issues of Intellectual Property Rights (IPR) brought into the project and the permissibility of derived works. If conditions relating to IPR are not specified, contributors, particularly commercial ones, may find participation either too costly (if their existing IPR are endangered) or not sufficiently attractive (if commercial proprietary products cannot be derived). For this reason, the resolution of these legal issues represents an essential precondition for OSI. The BiOS licence employed for OS biotechnology projects provides an example that illustrates the way IPR and knowledge sharing are combined. Contributors to a BiOS project retain their rights to pre-existing IPR as well as the right to apply for protection of their results later on. However, if they use other contributors' knowledge to derive these results, they must in return make their results accessible to all other contributors free of charge. In other words, results are shared openly within the community but may at the same time be used in proprietary solutions (BiOS 2008).
A caveat is in order, though. Some empirical cases show that licences are not prerequisite during the project early phases. This seems to be particularly true if the loss contributors incur from the hijacking of their ideas is small. As an example, think of hobbyists for whom contribution to the project is unconnected to their livelihood, or of companies that perceive the rewards of patenting to be low at this stage (von Hippel/von Krogh 2006; Franke/Shah 2003). Even then, licences are still important sustaining factors as not even hobbyists like to publicise their work entirely unprotected on a permanent basis. The "hijacking" of results often violates a sense of fairness that will be discussed in more depth in the following section.

Social Factors

Finally, we focus on the social factors that enable and sustain OSI, again starting with the enabling factors. An OSI project largely depends on its contributors and their intrinsic motivation to expend efforts and reveal their results (Raymond 2001). Many open source projects in the past never really took off due to low levels of participation (Shirky 2007). The Ligeti Stratos project, concerned with the development of a small, light-weight manned aircraft, seems to be a case in point (Ligeti Stratos 2008). Therefore, any OSI project must be able to draw on a sufficient number of potential contributors who not only have access to the knowledge and equipment required to participate, but also have the motives and interests the project appeals to. The specific project characteristics determine the size that actually constitutes a sufficient pool of potential contributors.
A second factor is the regulation of participation. By limiting access, as in the OSS cases cited above, actors can ensure that the other contributors match the requirements posed by the project, e.g. in terms of their knowledge or background. While for many OSI projects access restrictions are not necessary, they may be indispensable when too many participants would otherwise refuse to contribute, e.g. for fear of competitors gaining knowledge on sensitive products.
Social factors also play a prominent role in sustaining the actors' participation in the project after its inception phase. One important factor in this regard is self-governance, i.e. the absence of external interference which is often perceived to be controlling. External interference impedes the perceived fairness of the collaboration process, thereby reducing the actors' motivation to contribute (Markus/Manville et al. 2000). At the same time, the example of the OpenSolaris software shows that self-governance is not essential for the project set-up as long as the community expects to become self-governing after some initial period (LeMay 2006).
Related to the issue of self-governance, the sustainability of OSI projects is strengthened if a code of conduct is developed and maintained. In OSS projects, it has been found that not only do licences ensure compliance but so does the enforcement of shared norms (Kogut/Metiu

2001). Other OSI projects often feature codes of conduct that can be made explicit in documents sometimes called a “constitution”. To give an example of the importance of common norms beyond licence conditions, software maker Xara tried to take their flagship software Xara Xtreme open source in 2005 and failed. Following a broad consensus among the OSS community, many programmers refused to work on the code because they felt Xara was not acting according to the norms of “good OSS citizenship” (Willis 2007).
Instances, in which the behaviour of a participant is disputable, require mechanisms of conflict resolution. Otherwise, there is a risk that many volunteers abandon the network or many incompatible versions emerge out of the project. Conflicts are usually resolved by a central coordinator or a coordinating group with more or less hierarchical structures (Kogut/Metiu 2001). Two other issues raise the supposition that some centralisation may be necessary for OSI projects: the problem of ‘uninteresting’ tasks and the question of overall project direction. While it has been argued that even tasks that seem repetitive and uninspiring can actually be fruitful for some actors (Lakhani/von Hippel 2003), it is doubtful whether this is always true. The development of the project in line with its goals cannot be taken for granted either, as many OSS examples demonstrate (Constantine 2007). Therefore, OSI projects, at least if they attract more than a handful of contributors, are likely to require some central coordinating institution.
To conclude our analysis of the factors enabling and sustaining OSI projects we summarise our findings in the following figure.

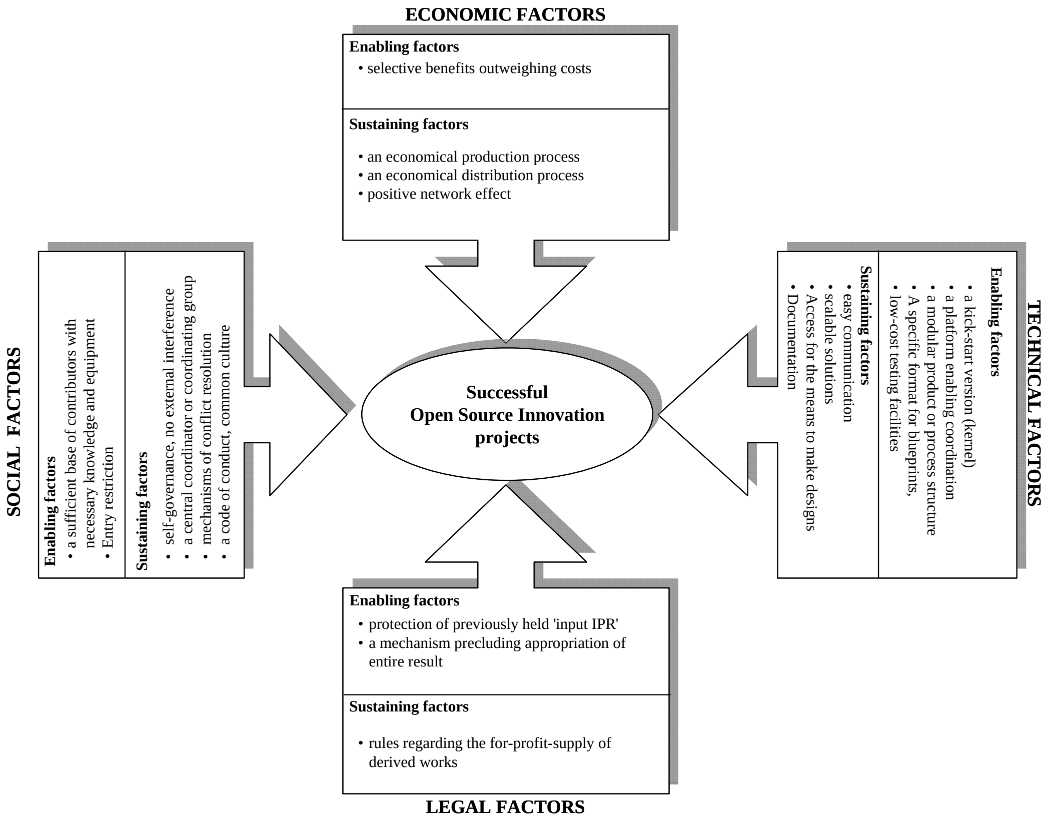

Figure 1: Economic, technical, legal, and social factors for the success of OSI projects

5. Conclusions and Directions for Future Research

This paper extends the principles of open source software development to a non-industry-specific level and introduces the Open Source Innovations (OSI) model. The discussion begins with an examination of the literature on OSS to identify the characteristics of its development. Based on this, our first contribution is a derivation of OSI from the OSS development model. To demonstrate that OSI is an innovation model in its own right, we examine the main differences to other related terms in the literature such as the private-collective model, commons-based peer production, R&D networks, etc. The second contribution is the analysis of the factors that need to be fulfilled in order for OSI projects to be successful. First, we make the distinction between four categories of factors: economic, technical, legal, and social. Second, in each category, we differentiate between enabling and sustaining factors. The enabling factors must be met when the project begins, whereas sustaining factors must be satisfied as the project progresses.

Our research in the future will be motivated by many questions that are still unanswered. First, little is known on the industrial sectors, in which OSI is practiced. Therefore, are there sectors that are more suitable for OSI processes than others? Second, it is important to recall that enabling and sustaining factors have been discussed from a theoretical viewpoint. An empirical verification is desirable, as it may point to additional factors or qualify our findings for specific industry contexts. Third, the question remains whether some factors are more critical than others. Fourth, the mechanisms that lead to the emergence of projects need to be studied.

We will analyse these questions within our research project over the next two years. We will conduct interviews with experts from academia and industry. The knowledge gained from these interviews, coupled with theory, will enable us to develop a questionnaire, which will be sent to a large number of companies in order to conduct a large-scale empirical study. In this way, we can advance theory building in the field of OSI and derive implications for management practice and business research.

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