Raasch, Christina; Herstatt, Cornelius; Abdelkafi, Nizar

Working Paper

Open source innovation: Characteristics and applicability outside the software industry

Working Papers / Technologie- und Innovationsmanagement, Technische Universität Hamburg-Harburg, No. 53

Technologie- und
Innovationsmanagement

Working Paper / Arbeitspapier

Open Source Innovation – Characteristics and Applicability Outside the Software Industry

Dr. Christina Raasch
Prof. Dr. Cornelius Herstatt
Nizar Abdelkafi

März 2008
Arbeitspapier Nr. 53

Technische Universität Hamburg-Harburg

Schwarzenbergstr. 95, D-21073 Hamburg-Harburg
Tel.: +49 (0)40 42878-3777; Fax: +49 (0)40 42878-2867

www.tu-harburg.de/tim

Open Source Innovation – Characteristics and applicability outside the software industry

by Christina Raasch[1], Cornelius Herstatt[2] and Nizar Abdelkafi[3]

[1] raasch@tu-harburg.de

[2] c.herstatt@tu-harburg.de

[3] nizar.abdelkafi@tu-harburg.de

Abstract

Motivation of this paper is to discuss that the open source model of innovation does not only seem practical in the software industry, but also in various other industrial contexts. We develop the concept of Open Source Innovation (OSI) as a generalisation of the open source model of software development (OSS). Our definition centres on the collaboration of volunteers and the free revelation of knowledge between actors. Since OSI exhibits important differences to several related concepts in the literature, we conclude that it is an innovation model in its own right, deserving more attention and research. We further proceed to identify aspects affecting the application of the OSI model in industry practices, grouping them into economic, technical, legal, and social factors. Based on these results as well as expert interviews, we find that the applicability of OSI is primarily determined by the characteristics of, first, the innovation object and, second, the group of contributors, rather than the industrial sector. Finally, we advance propositions on the employment of OSI in industrial practice, relating its feasibility to the innovation object and the group of contributors.

1. Introduction

Open Source (OS) has been emerging as an important parallel avenue to successfully developing software over the last decade. This development is under intense research but already constitutes a well accepted fact today. Vendors of proprietary software had to accept open-source solutions taking root and occasionally even taking the lead over proprietary products in many market segments [6]. Today a total of 170.000 Open Source Software (OSS) projects are registered on the Sourceforge database [53]. Linux alone has more than 29 million users [33]. In short: „The viability of the open source model of software development is not in question. It exists and works" [3, p. 3].

This success of OSS projects has attracted considerable attention from researchers and practitioners alike. In the academic literature, OSS is identified as an example of a "new innovation model" beyond markets, hierarchies and strategic alliances [42] that has also been referred to as the "community-based model" [50], the "open source method" [42] or "opensourcing" [1]. Several researchers believe that industries other than software may also witness open source development processes in the future, e.g. [28], [35]. Notwithstanding the assumed proliferation of OSS and even some observations of existing projects [50], [19], [43], the main body of research still focuses on the software industry itself. Limitations to the availability of successful empirical examples of this 'new innovation model' outside software may be a key reason for this gap.

Our paper aims to contribute to filling this gap and hence evolving this field of research by analysing conditions under which collaborative development projects built from voluntary contributions may take place in industries beyond software. To this end, we first develop the concept of Open Source Innovation (OSI) as a generalisation of the OSS model and relate it to existing models of collaborative development. In section 3, we describe critical aspects relating to the implementation of OSI projects, drawing both on previous research on OSS and examples from other industries. Based on exploratory interviews we conducted with OSI and industry experts as well as leading researchers, in section 4 we develop propositions on the applicability of the Open Source Innovation model outside the software industry. Finally, section 5 summarises these first results and suggests directions for future research.

2. OSI: The open source model of innovation – beyond the software industry

Open source software development

According to [56, 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" (similarly [41], [48]).[1] Unrestricted access, utilisation, modification and redistribution of source code constitute the characteristics of OSS [7]. They "keep the code in the commons" [23, p. 257], i.e. they preclude the appropriation of the created code by one single actor, and thereby support the continued motivation of users to contribute to the project [14].

At the same time, OSS projects feature „typical open source development practices" [56, p. 1151]; "general characteristics" and "structural conditions of successful OSS projects" [18, p. 1161] have been identified as well as constituent OSS "ingredients" [28, p. 28]. The assumption that the OSS model may be transferable to other industries usually refers not only to the fundamental licensing conditions, but also to these practices and "ingredients" [56].

Five groups of such 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, (4) project governance and organisation, and (5) technical prerequisites. This partition builds on the trisection of the OSS literature proposed by [59]. 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 paper.

(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 about 50% of all lines of code, mostly with full knowledge of their supervisors [25], [26]. The range of motives, which stimulate commercial companies and single contributors to participate in software development has been a core issue for researchers ([59] provide an overview). The expected utility is frequently incommensurable; rent-seeking and donating behaviour co-exist, without one crowding-out the other [14], [47]. Free-riding behaviour is curbed by the selective accrual of the benefits of contributing, which can make code contribution self-rewarding [57].

(2) As a basic rule, 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 [58]. In some projects, the community even sets more stringent access rules that

[1] Note: OSS licences come in considerable variety. To date, 65 licence texts have been accredited by the Open Source Initiative (www.opensource.org). Under all licences, OSS code is a commons open for all to use and modify. Differences lie in the extent to which public property may be combined with proprietary solutions.

exclude some potential contributors, as examples in the computer games industry illustrate. In any case, the decision to join the developer community, either as an individual contributor or as an organisation, is taken voluntarily, without any form of coercion. Once accepted, individual participants can choose to volunteer effort based entirely on their own preferences, e.g. [45], [3]. In the case of commercial participants, by contrast, contributing may be delegated to some member within a hierarchical organisation.

(3) 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 [35] or a feeling of reciprocal obligation [51] within a system of network-generalised exchange [13], [62]. Access to results is not restricted to any particular group, allowing free-riders to profit from results without recompense or reciprocal effort [42].

(4) Project organisation and governance exhibit complex patterns that are still being researched. 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 [7, p. 1246]. Self-governance likewise plays a prominent role, e.g. inasmuch as autonomy helps to keep up intrinsic motivation [12]. Peer-review serves as a means of quality assurance [21]. The group itself ensures that its code of conduct, be it explicit or tacit, is observed by all contributors [42], [40].

The importance of self-organisation and self-governance notwithstanding, successful OSS projects strongly rely on leaders to take care of information, agency, and coordination problems [35]. Leadership derives from competence rather than ownership of assets [7], [18]. It can be executed by “a benevolent dictator together with tribal elders” as in the case of Linux [45, p. 45] or be implemented through qualified voting systems and coalitions as with Apache [23].

(5) From a technical perspective, collaborative development requires two fundamental conditions. First, a modular code architecture enables collaborative development and helps to keep individual contributions manageable in terms of required effort and expertise [38], [22]. Second, low-cost communication tools and platforms are needed to support the development process [18, p. 1161].

Taking OS beyond software: The open source innovation (OSI) model

As mentioned at the outset of this paper, several experts discuss the possibility of the OSS model of innovation being applied in industries beyond software. Innovative product offerings are supposed to become attainable in the future by the emulation of the OSS model in other industries [8].

The discussion on the transfer of the OSS development model to other industries necessitates a closer look at the potential shape of the transferred model: Which aspects are applicable in other industries? How can software-specific conditions be adapted? Which additional factors need to be taken into account? It stands to reason that a direct transplantation of the OSS model to industries at large may not be feasible due to a number of specific context factors and conditions in the software industry. To raise the OSS model to a non-industry specific level, therefore, we propose a generalised concept called Open Source Innovation (OSI).

We define Open Source Innovation as an innovation, which is (1) generated through volunteer contributions and (2) 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 for anyone wishing to exploit them, allowing utilisation, modification, and re-distribution.

Wikipedia as the best-known supplier of open content is the most-cited, but not the only example of OSI. Other instances 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), or in architecture (e.g. the Open Architecture Network). Many OSI projects are still in their infancy or testing phase, while others have been fully functional for several years.

Relation of OSI to other models of collaborative innovation

Our model builds on and intersects with several of the models of collaborative innovation proposed in the literature. The “private-collective model” [56] 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 involving several contributing actors, in turn requiring organisational mechanisms to coordinate the efforts expended by different actors. These characteristics can be encompassed by the private-collective model but are not required *per definition*. In addition, the exploitation of the exchanged 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 [2], [39], [36], which describes “the free exchange of information about new techniques and plant designs among firms in an industry” [2, 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 [36]. OSI, by contrast, is a broader concept as it includes the invention and exploitation phase and is not restricted to commercial contributors from the same industry.

Benkler [5] 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 in that it allows some hierarchical element of coordination (see also [16]), and it is more stringent inasmuch as peer-production allows some restrictions on sharing, particularly “limited-access common resources” where access is limited to a well-defined number of actors [5, p. 61].

Moreover, OSI needs to be contrasted to R&D networks established by companies [44], [49], [37], to user innovation networks [54], and to the community-based model of innovation [50]. 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.

Having generalised the OSS model of innovation to the OSI model, we need to analyse the factors influencing its applicability in industry practice.

3. Critical aspects for implementing OSI projects beyond software

Aspects affecting the applicability of OSI will be discussed in this section from a theoretical point of view. They provided the foundation for a number of exploratory expert interviews we conducted, the findings of which will be described in the subsequent section.

To give structure the factors influencing the implementation of OSI in a practical context, we use a four-prong framework applied by [29] and adapted by [9] to study the barriers to user innovation. Accordingly, we distinguish economic, technical, legal, and social aspects.

Economic aspects

An OSI project may be initiated by a group of actors, be they individuals, organizations or a mixture of both. In many cases they may be product users. With regard to user innovation, von Hippel [55, 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 more likely to emerge if product development resources at the disposal of users are superior to the resources a firm can supply with respect to the innovation task. The cost of the development project needs to be juxtaposed to the benefits accruing to both the contributor himself and the community, i.e. positive external effects. If the sum of all benefits exceeds developments costs, the project could be viably conducted as OSI.

At the micro-level, 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, these benefits and costs are not necessarily monetary, since the vast majority of human behaviour cannot be monetized [60, p. 226]. What is crucial here is the selectivity of their accrual, i.e. the fact that contributors not only have higher costs than free-riders, but also benefit to a larger degree.

For commercial contributors the participation in OSI projects is appealing if it increases profit or promotes the attainment of other strategic goals. With reference to OSS, Henkel [17] identifies five groups of motives for commercial contributors to participate in development. Among them are benefits from standardization, the hope to gain well-qualified external support for their own development efforts, and the increase of customer demand for their product or service offerings that are complementary to the project.

It should be noted that the actors' behaviour is based the *expectation* of the costs and benefits of sharing knowledge and contributing to OSI projects, qualified by the actors' situation-specific degree of risk aversion. To give an example, a company may be hesitant to reveal knowledge if it has difficulty gauging the value this knowledge may have for competitors at some later stage.

Technical aspects

From a technical perspective, OSI projects can only be launched if a basic product design is available. In OSS, this is called the kernel. For physical products, the basic design is a set of preliminary design concepts, which are freely revealed for further development. A basic design is necessary at the inception to set the project goal, motivate actors to contribute to the project, and guide the design effort [46]. Its further development presupposes that the format in which it is released is geared to comfortable modifiability.

OSI projects critically hinge on easy communication between all contributors, a requirement that becomes more difficult to meet as the group of participants grows. Therefore, the Internet usually, but not always represents an important platform for coordinating project-related effort and sharing results with a large audience [45].

The advantages of OSI projects cannot be realised, unless each member can build upon the ideas of others. This requires that he can find, understand and revise the blueprints of his peers. Linked to a sound solution for a communication platform, therefore, there must be a repository for current as well as preceding designs including detailed documentation. Moreover, access and modification is only possible if all participants have easy if not free access to the means and tools necessary to create and modify product designs. Examples of OSI in the automotive industry show that closed access to tools (in this case CAD software) put a significant strain on OSI projects.

Legal aspects

In order to apply the OSI model outside software, the legal environment needs to be shaped to fit project needs and to safeguard the economic factors already discussed. Many legal questions still require research, in particular regarding the sharing and protection of intellectual property rights in OSI and the relationship between the two. What is the role of IPR within each project? If necessary, how can IPR be created and shared in a manner that does not stifle volunteer contributions from the developer community? Where there are commercial suppliers or manufactures cooperating with the developer community, the exchange of knowledge with these groups likewise requires rules, both to encourage their involvement and to regulate their activities.

In some cases, actors decide to freely reveal their innovative concepts only because they can protect their work. For instance, placing a patent on an object before sharing it within an OSI project precludes “hijacking” [40, p. 1181] by other participants. Though it may seem counter-intuitive, even the results of the OSI process may require patent protection. If, for instance, the OSGV project, which aims to design and produce cars according to OS principles, did not protect its designs through patents it could then licence to manufacturers, anybody could set up a plant to produce the OSGV design. This, apart from posing safety issues, could materially lessen the incentive of manufacturers to invest in tools and equipment specifically required to produce the OSGV design. Thus, Weber’s [60, p. 191] statement that “[i]t is not an oxymoron […] to protect open source code with copyright law” by extension also holds for OSI. However, OSI projects may have to deal with both patent law and copyright law, where the former often proves more difficult to handle.

Many experts ascribe a large fraction of the success of OSS to the creation of tailored licensing conditions [42]. Outside the field of software products, too, OSI projects are supported by licensing schemes, e.g. in the case of the Simputer hand-held, the Biobricks project, or open content projects coming under Creative Commons licences [31]. Licenses are important because they specify the conditions for using, modifying and appropriating innovative results. Still, some empirical cases show that licences can be dispensed with during the early project 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 [15]. In the medium term, however, licences may prove indispensable as not even hobbyists like to publicise their work entirely unprotected on a permanent basis [42, p. 166].

Social aspects

To conclude this section, we focus on the social aspects affecting the implementation of the OSI model. An OSI project largely depends on its contributors and their motivation to expend efforts and reveal their results [45]. Many open source projects in the past never really took off due to low levels of participation [52]. The Ligeti Stratos project, concerned with the development of a small, light-weight manned aircraft, seems to be a case in point [32]. As a vital prerequisite, 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. What constitutes a sufficiently large pool of potential contributors is determined by the specific project characteristics.

A second aspect that can prove essential for some OSI projects is the regulation of participation. As with some OSS projects, actors can limit access to 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 may not be necessary, they can prove indispensable when many participants would otherwise refuse to contribute, e.g. for fear of competitors obtaining crucial knowledge at an early stage.

Social aspects 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 felt to be controlling. External interference impedes the perceived fairness of the collaboration process, thereby reducing the actors' motivation to contribute [34]. At the same time, the example of the OpenSolaris software shows that self-governance is not essential as long as the community expects to become self-governing later on [27]. Related to the issue of self-governance, a code of conduct can support the viability of OSI projects. Not only do licences ensure compliance but so does the enforcement of shared norms [23]. The example of Xara Xtreme illustrates the importance of common norms: Software maker Xara's attempt to take their flagship software open source failed because, following a broad consensus among the OSS community, most programmers refused to work on the code. They felt that Xara was not acting according to the norms of "good OSS citizenship" and therefore did not volunteer any effort [61].

Instances, in which the behaviour of a participant is disputable, require mechanisms of conflict resolution. Otherwise, many volunteers may abandon the project or split off and continue in their own, producing a second version that becomes incompatible with its parent project. In OSS development, this is called code-forking [10]. Conflicts are usually resolved by a central coordinator or a coordinating group with more or less hierarchical structures [23].

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 [24], it is doubtful whether this is always true, or whether certain tasks may remain undone unless assumed by some central institution. The development of the project in line with its overarching goals cannot be taken for granted either [11]. These points suggest that OSI projects, at least if they attract more than a handful of contributors, are likely to require some central coordinating institution.

The critical aspects for implementing OSI projects are summarised in Fig. 1.

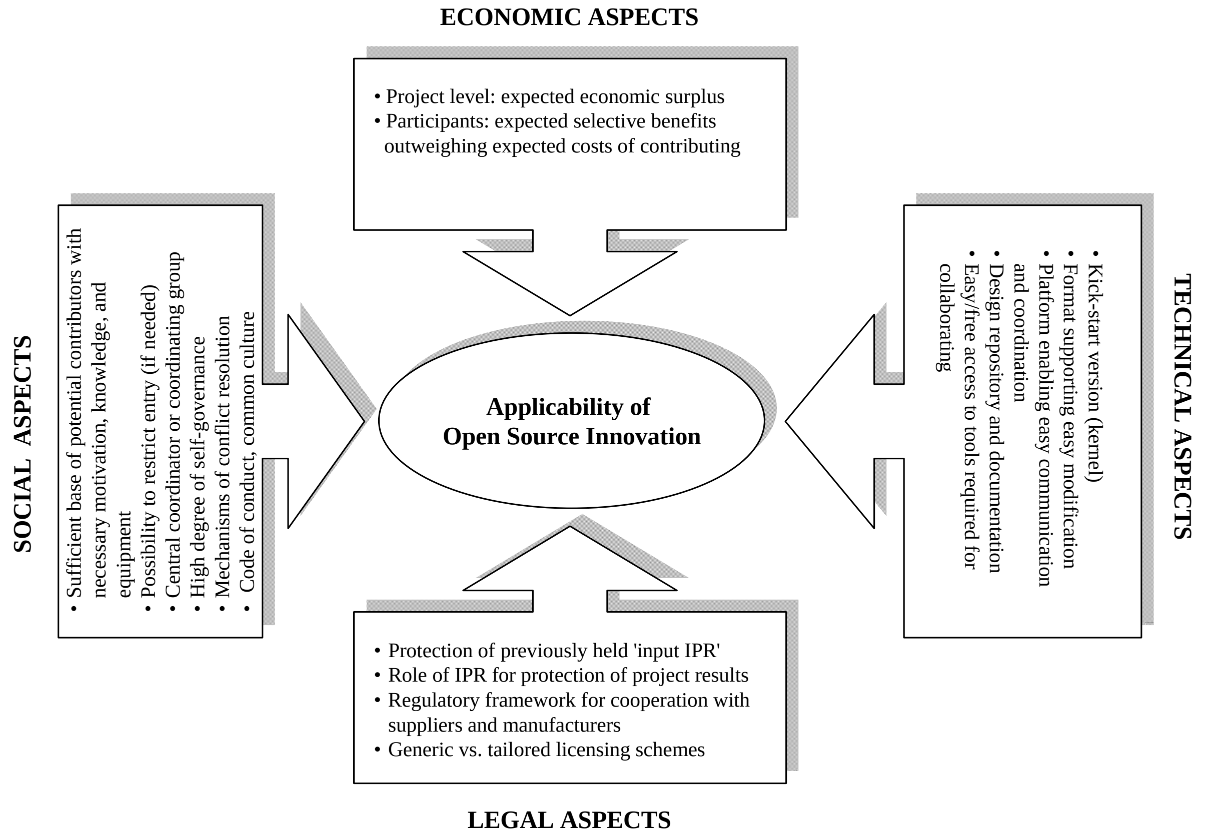

Fig.1 Critical aspects for implementing OSI projects

4. First findings on the applicability of OSI in an empirical context

Based on the existing literature and some case examples we analysed aspects to be considered when planning to conduct an OSI project in the previous section. To improve our understanding and support our arguments we conducted 18 exploratory interviews with experts from industry, government institutions and academia. Industry experts were mostly high-ranking members of organisations either involved in collaborative innovation projects and/or interested in OSI with regard to future projects. Particular focus was given to the automotive and life science industries since the academic literature generally assigns these sectors a high potential for OSI.

A key result which was uniformly confirmed by all interviewees is the following: The question whether OSI projects are feasible or not is not primarily determined by the industrial sector in which they are situated. In other words, trying to distinguish industries that are suitable for OSI from industries that are not is not a promising exercise. Rather, the applicability of OSI is determined jointly by two contextual dimensions, (1) the characteristics of the innovation object and (2) the characteristics of the group of contributors. Ad (1): The innovation object can be a product or process; it can be physical or non-physical, simple or complex, modular or monolithic, etc. Ad (2): The group of contributors to the project may be typified by its size, the motivations of its members to participate, the degree of heterogeneity of their knowledge and their needs, and so forth. In short, an analysis restricted to industry characteristics would only give insufficient insights into the specific context of OSI application, which actually determines the feasibility of OSI processes, and vice versa.

Proceeding on this basic premise and drawing on insights gained during expert interviews, we advance three propositions for each of the two dimensions. Thereby we hope to further stimulate analysis of the OSI model, particularly the determinants and limitations of its applicability outside the software industry. Fig. 2 provides some selected examples of statements by interviewees, which led to the formulation of the propositions.

(1) The characteristics of the innovation object: Modularity and complexity

The development of software systems requires an efficient way of coordinating actors' contributions. The division of the project into smaller tasks not only keeps the required effort at levels that are manageable for volunteer contributors, but also renders it possible for developers to work without constantly stepping on each others' toes. Though the different parts of the code are produced separately, they fit together, thereby enabling to the whole system to work. The corresponding property of the innovation object, enabling OSS projects to be organized in this way, is called modularity. According to [4, p. 151], a "modular system is composed of units (or modules) that are designed independently but still function as an integrated whole."

Because software products are complex systems, modularity is a prerequisite to reduce the complexity of coordination. For OSI projects in general, however, a high level of modularity of the innovation object is likewise conducive, but not strictly required. In other words, some OSI projects are feasible despite non-modular objects. Many objects that are inherently not modular (e.g. shoes or garments), can be accessible to OSI when developers can work on the entire object. Consequently, we believe that a high level of modularity is required, only when the innovation object is complex. Simple objects may be developed according to OSI principles, even when they are non-modular (integral). Thus, we can derive the following proposition:

Proposition (1a): The applicability of OSI depends jointly on the degree of modularity and the degree of complexity of the innovation object. High complexity necessitates a modular architecture, while simple objects may be amenable to OSI despite modularity being low.

Challenges of physical products

All OSI projects in which the result is not digital in nature need to accomplish the crucial transition from ideas (e.g. in the form of technical drawings) to physical products. This transfer renders the application of OSI outside the realm of information goods more complicated. To run, test, and debug a software application, developers need only a computer and a compiler. Building and testing product prototypes, however, may be rather costly. Online toolkits can alleviate the problem by offering simulation and virtual testing facilities [20]. The remaining costs may be borne by single developers, at least when the product is relatively simple, such as a skateboard. But when products are complex and production presupposes large investment, developers need to acquire the necessary finance. Commercial companies or research institutions are potential partners supporting the making of prototypes [30]. Interviews conducted in the automotive industry, where each prototype can cost more than one million US dollars, confirm that this aspect is not only time-consuming but may even put a halt to the entire OSI project.

By extension, not only prototyping, but also manufacturing and distributing a physical product require specific attention. In the case of software, the costs of production and distribution are virtually zero because code can be spread over the Internet. With OSI, by contrast, production and distribution are not only likely to be more costly, but also to require significant up-front investment. This investment will only be undertaken by commercial companies based on the expectation of sufficient returns. Product safety issues may make production yet more critical.

For such reasons OSI processes may viably be applied to the development of bicycles or a small module required for building large passenger aircraft, but not to the entire airplane.

Proposition (1b): OSI projects are more likely to occur if the costs of transforming innovation-related information into physical objects are low.

Managing development cost

OSI projects with objects that require a high level of effort due to their complexity and scope are very demanding to realise: Large-scale project management puts high demands on coordinators; and the sheer amount of work to be done may prove too much for the contributing community of volunteers, especially when it is still growing. Considering that, to have 50 active contributors, projects require approx. 5000 registered participants, it stands to reason that reach needs to be built before shouldering very large tasks. In such cases, it seems advisable to narrow the project scope to crucial components by incorporating existing proprietary solutions into the design, at least during the earlier stages. These solutions can be successively displaced by others developed by the community to fit more closely to project needs. Interviewees confirm that some larger OSI projects indeed pursue a sequential approach based on this reasoning.

Proposition (1c): The level of development effort required for an OSI project affects its feasibility. Proprietary solutions can be incorporated into OSI projects to narrow the project scope and thereby to reduce requisite effort for the developer group.

(2) The characteristics of the group of contributors: Project-relevant knowledge

Based on our expert interviews, we find that the applicability of the OSI model increases when knowledge on the innovation object is more dispersed, i.e. when the number of potential contributors is large. Compare, for instance, a project aiming to develop a mousetrap to one striving to develop a gasket for vacuum pumps used in cluster physics. It is obvious that more people are knowledgeable about the former. Thus, it is more likely to find a sufficient number of contributors to successfully develop mouse-trap than a high-performance gasket.

Proposition (2a): A wide dispersion of the knowledge related to the innovation object is conducive to OSI applicability.

Sharing the risk of project failure

During our interviews, several industry experts stated that, despite the opportunities they believed OSI to present, the risk of attempting this novel approach seems excessive. Specifically, they referred to the risk of not being able to recoup R&D investment due to competitors creaming off innovation results when the legal framing of the project proved insufficient. Some interviewees asserted, however, that they would deliberate contributing to OSI projects if third parties, particularly public institutions, demanded an open source approach and provided some funding support in return. Thus it seems that the middle ground between publicly funded R&D on the one hand and commercial R&D projects on the other hand might be more accessible to OSI than projects that are entirely funded from private resources.

Proposition (2b): OSI projects, particularly projects with commercial contributors, are more likely to occur when third parties set the rules and bear part of the cost.

	Industry	Academia	Other
1a: The applicability of OSI depends on modularity and complexity.	(4) ”Modularity is extremely important.“ (1) “There is a lot of innovation going on because the [object] is small and simple.“	(3) ”In our experience to date, projects with more modular products do not necessarily attract more contributors.“	(8) ”Modularity allows you to stake claims [to parts of the result…] ‚We contributed this module.‘“
1b: OSI projects are more likely to occur if the costs of transforming innovation-related information into physical objects are low.	(6) ”Software is easy. It is just code and files. There is no cost of production and distribution… The cheaper, the better.“ (15) ”You simply cannot compare software and biotech. In biotech you have long investment cycles and huge investment.“	(12) ”Building an aircraft is a huge design effort and a serious money problem“ [in an open-source project set-up].	(10) ”Non-physical products are most suitable for open source.“
1c: Proprietary solutions can be incorporated into OSI projects to narrow the project scope.	(6) [Our licence] ”just refers to the interfaces… Suppliers either have standardised solutions or can adapt their solution to the interface and requirements… The crucial elemement is that you define interfaces such that you get the solution, plug it in, and it works well with your design.“	(12) ”You need to selectively choose which parts of the design you want to control […] The rest you can outsource.“ (14) ”You need to look at the product in terms of its constituent parts, not in its entirety.“	(8) “Some process steps can be licensed to contract research institutions.”
2a: A wide dispersion of the relevant knowledge is conducive to OSI applicability.	(5) ”In our experience, those projects are most successful which appeal to a broad audience and do not necessitate a lot of knowledge.“	(11) ”The dispersion of knowledge is an important factor… [Dividing effort] allows the institutional creation of a low-cost situation“	(10) [For OSI] ”you want broad expertise and a heteogenous group of contributors… Thus the development cost can be borne by many shoulders.“
2b: OSI projects are more likely to occur when third parties bear part of the cost.	(2) ”Open source can work in areas where competition still exists but is given a ‚peace frame‘ by public funding.“	(11) ”Another question affecting the applicability of OSI is who bears development costs. If society bears part of the cost, rather than Individuals, OSI is more likely.“	(10) “We work with public money. Thus we try to give as many people as possible access to our results […] We need to avoid unnecessary duplication of work.“
2c: Commercial contributors are more likely to participate in projects not closely related to their competitive advantage.	(2) ”No company can afford to give away knowledge which gives them their competitive edge.“ (4) ”Production efficiency is a good field [for OSI]. […] Production processes are not mission critical. […] And if someone profits more than others, there is not much harm done.“	(12) ”There is a rivalry threshold beyond which open source does not work very well.“	(13) “In every industry, there are processes that can be outsourced […] This is not a call to neglect common business sense. You just need to know where to apply the lever.“

(x) Numbers identify different interviewees

Fig. 2 Statements by interviewees pertaining to our propositions – Some examples

The fear of too much openness

Individuals who contribute to OSI projects are often not striving for monetary rewards; other intrinsic motives, such as the fun of designing a solution, or extrinsic factors such as the wish to build reputation as an expert usually drive them to devote effort to the project. Decision-makers in commercial firms, by contrast, choose to contribute only if it promotes the attainment of profit in the short or long term. As already discussed, the fear that the participation in OSI projects will actually endanger profit made many of the industry experts we interviewed hesitant to contribute to OSI projects. However, some interviewees, based on opportunities they perceived to derive from OSI, stated that they would consider experimenting with OSI in areas not directly affecting their competitive position. Tasks which it is important to accomplish well but which do not lie at the core of companies' competitive advantage were therefore perceived to be more amenable to OSI processes, at least in the medium term.

Proposition (2c): Commercial contributors are more likely to participate in OSI projects not closely related to their competitive advantage.

5. Conclusions and directions for future research

The main motivation of this paper is the empirical observation that the open source model of innovation does not only seem practical in the software industry, but also in various other contexts. We derive the concept of Open Source Innovation (OSI) as a generalisation of the open source model of software development (OSS). Our definition centres on the collaboration of volunteers and the free revelation of knowledge among actors. Since OSI exhibits important differences to several related concepts in the literature, we conclude that it is an innovation model in its own right, deserving more attention and research. We proceed to identify aspects affecting the application of the OSI model in industry practice, grouping them into economic, technical, legal, and social factors. Based on these results as well as expert interviews, we find that the applicability of OSI is primarily determined by the characteristics of, first, the innovation object and, second, the group of contributors, rather than the industrial sector. Finally, we advance propositions on the employment of OSI in industrial practice, relating its feasibility to the innovation object and the group of contributors.

The propositions derived in this paper will shape our future research. The interviews we conducted provide preliminary evidence on the importance and validity of these propositions. The next step in our two-year research project will be in-depth empirical studies involving companies from different industrial sectors to support our current findings. We will analyse the conditions under which OSI seems a viable model for industry practice and propose areas that may gain from the implementation OSI in the future.

The revolution that open source has caused in the realm of software over the last decade justifies a close scrutiny of the conditions and limitations under which other areas may be affected by similar phenomena in the years to come. Our paper aims to show that companies in many industries should watch out for the opportunities Open Source Innovation may offer to them.

Acknowledgements

We are indebted to Carliss Baldwin, Margit Osterloh, Frank Piller for their advice on this paper.

List of references

[1] Agerfalk, P. J. and B. Fitzgerald; "Opensourcing to an unknown workforce: Exploring opensourcing as a global sourcing strategy," *MIS Quarterly*, in press.

[2] Allen, R. C.; "Collective invention," *Journal of Economic Behavior and Organization*, vol. 4, pp. 1-24, 1983.

[3] Baldwin, C. Y. and K. B. Clark; "The architecture of cooperation: how code architecture mitigates free riding in the open source development model," Harvard Business School, working paper, 2003.

[4] Baldwin, C. Y. and K. B. Clark; "Managing in the age of modularity," in *Managing in the Modular Age*, R. Garud, A. Kumaraswamy and R. N. Langlois, Ed. Malden et al.: Blackwell Publishing, 2003.

[5] Benkler, Y.; *The wealth of networks - How social production transforms markets and freedom*. New Haven, CT: Yale University Press, 2006.

[6] Benussi, L.; "The evolution of free/libre open source software," working paper, 2006, Retrieved 2/29/08 World Wide Web, http://opensource.mit.edu/papers/Benussi(2006)_The_evolution_of_FLOSS_1.pdf.

[7] Bonaccorsi, A. and C. Rossi; "Why Open Source software can succeed," *Research Policy*, vol. 32, pp. 1243-1258, 2003.

[8] Braman, S.; "An economy of long term views," Retrieved 2/29/08 World Wide Web, http://www.bpb.de/themen/QNGT40,0,0,An_economy_of_long_term_views.html.

[9] Braun, V. R. C.; Barriers to user-innovation & The paradigm of licensing to innovate. Hamburg, PhD Thesis, Germany: Hamburg Technical University, 2007.

[10] Comino, S. and F. M. Manenti, *Dual licensing in open source software markets*. 2007, Department of Economics, University of Trento, Italia.

[11] Constantine, L.; "The Open Source solution - Why not use a communal approach to fix software?," *Technology Review*, Jan. 2007, Retrieved 2/29/08 World Wide Web, http://www.technologyreview.com/Infotech/17997/?a=f.

[12] Deci, E. L. and R. M. Ryan; "The "what" and "why" of goal pursuits: Human needs and the self-determination of behaviour," *Psychological Inquiry*, vol. 11, pp. 227-268, 2000.

[13] Ekeh, P. P.; *Social exchange theory: The two traditions*. Cambridge, MA: Harvard University Press, 1974.

[14] Franck, E. and C. Jungwirth; "Reconciling rent-seekers and donators - The governance structure of open source," *Journal of Management and Governance*, vol. 7, pp. 401-422, 2003.

[15] Franke, N. and S. Shah; "How communities support innovative activities: an exploration of assistance and sharing among end-users," *Research Policy*, vol. 32, pp. 157-178, 2003.

[16] Garcia, J. M. and W. E. Steinmueller; "Applying the open source development model to knowledge work," Science and Technology Policy Research, Information, Networks & Knowledge Research Centre, Working paper, Jan. 2003, Retrieved 2/29/08 World Wide Web, http://siepr.stanford.edu/programs/OpenSoftware_David/oswp2.pdf

[17] Henkel, J.; "Patterns of free revealing - Balancing code sharing and protection in commercial open source development," working paper, 2004.

[18] Hertel, G., S. Niedner and S. Herrmann; "Motivation of software developers in Open-Source projects: an internet-based survey of contributors of the Linux kernel," *Research Policy*, vol. 32, pp. 1159-1178, 2003.

[19] Honsig, M.; "Das offenste aller Autos," *Technology Review*, 2006, Retrieved 2/29/08 World Wide Web, http://www.heise.de/tr/Das-offenste-aller-Autos--/artikel/68663/1/0

[20] Jeppesen, L. B.; "User toolkits for innovation: Costumers support each other," *Journal of Product Innovation Management*, vol. 22, pp. 347-362, 2005.

[21] Johnson, J. P.; "Collaboration, peer review and open source software," *Information Economics an Policy*, vol. 18, pp. 477-497, 2006.

[22] Kirchgässner, G.; "Towards a theory of low-cost decisions," *European Journal of Political Economy*, vol. 8, pp. 305-320, 1992.

[23] Kogut, B. and A. Metiu; "Open-source software development and distributed innovation," *Oxford Review of Economic Policy*, vol. 17, pp. 248-264, 2001.

[24] Lakhani, K. R. and E. von Hippel; "How open source software works: "free" user-to-user assistance," *Research Policy*, vol. 32, pp. 923-943, 2003.

[25] Lakhani, K. R. and B. Wolf; "The Boston Consulting Group - Hacker Survey," working paper, 2002.

[26] Lakhani, K. R. and B. Wolf; "Why hackers do what they do: Understanding motivation and effort in free/open source software projects," in *Perspectives on Free and Open Source Software*, J. Feller, B. Fitzgerald, S. A. Hissam and K. R. Lakhani, Ed. Cambridge, MA: MIT Press, 2005.

[27] LeMay, R.; "OpenSolaris one year on: Sucess or failure?" Retrieved World Wide Web, Retrieved 2/29/08 World Wide Web, www.builderau.com.au/news/soa/OpenSolaris_one_year_on_Success_or_failure_/0,339028227,339257702,00.htm.

[28] Lerner, J. and J. Tirole; "The economics of technology sharing: Open Source and Beyond," working paper, 2004.

[29] Lessig, L.; *Code and other laws of cyberspace*. New York: Basic Books, 1999.

[30] Lettl, C., C. Herstatt and G. H. Georg; "Users' contributions to radical innovation: evidence from four cases in the field of medical equipment technology," *R&D Management*, vol. 36, pp. 251-271, 2006.

[31] Liang, L.; "Guide to open content licenses," Piet Zwart Institute, 2004, Retrieved 2/29/08 World Wide Web, http://pzwart.wdka.hro.nl/mdr/pubsfolder/opencontent.pdf

[32] Ligeti Stratos; "World's first open source aircraft", Retrieved 2/29/08 World Wide Web, http://www.ligetistratos.com/.

[33] Linux; Retrieved 2/29/08 World Wide Web, http://counter.li.org/.

[34] Markus, M. L., B. Manville and C. E. Agres; "Innovation-Technology - What makes a virtual organization work?," *Sloan Management Review*, vol. 42, pp. 13-26, 2000.

[35] Maurer, S. M. and S. Scotchmer; "Open Source Software: The new intellecutal property paradigm," NBER Working Paper Series, working paper, 2006.

[36] Meyer, P. B.; "Episodes of collective invention," BLS Working Papers, working paper, 2003, Retrieved 2/29/08 World Wide Web, http://www.bls.gov/ore/pdf/ ec030050.pdf.

[37] Miotti, L. and F. Sachwald; "Co- operative R&D; Why and with whom?: an integrated framework of analysis," *Research Policy*, vol. 32, pp. 1481-1499, 2003.

[38] Narduzzo, A. and A. Rossi; "Modularity in Action: GNU/Linux and Free/Open Source Software Development Model Unleashed," working paper, 2003, Retrieved 2/29/08 World Wide Web, http://opensource.mit.edu/papers/narduzzorossi.pdf.

[39] Nuvolari, A.; "Collective invention during the British industrial revolution: The case of the Cornish pumping engine," *Cambridge Journal of Economics*, vol. 28, pp. 347-363, 2004.

[40] O'Mahony, S.; "Guarding the commons: How community managed software projects protect their work," *Research Policy*, vol. 32, pp. 1179-1198, 2003.

[41] Open Source Initiative; "The Open Source definition," 2006, Retrieved 2/29/08 World Wide Web, http://www.opensource.org/docs/osd.

[42] Osterloh, M. and S. Rota; "Open source software development- Just another case od collective invention ?," *Research Policy*, vol. 36, pp. 157-171, 2007.

[43] Pearce, M. and V. Ferguson; "A change of scenery - Open Source licensing and its application to the biotech industry," *Patent World*, 2006.

[44] Pyka, A. and G. Küppers; "Innovation networks : theory and practice," in *New horizons in the economics of innovation*, Cheltenham u.a.: Elgar, 2003.

[45] Raymond, E.; "The cathedral and the bazaar," *Knowledge, Technology, & Policy*, vol. 12, pp. 23-49, 1999.

[46] Raymond, E.; *The cathedral & the bazaar: Musings on Linux and Open Source by an accidental revolutionary*. Beijing et al.: O'Reilly, 2001.

[47] Roberts, J. A., I.-H. Hann and S. A. Slaughter; "Understanding the motivations, participation, and performance of open source software developers: A longitudinal study of Apache projects," *Management Science*, vol. 52, pp. 984-999, 2006.

[48] Rosen, L.; *Open Source Licensing - Software freedom and intellectual property law*. Upper Saddle River, NJ: Prentice Hall, 2005.

[49] Sakakibara, M.; "Cooperative research and development: who participates and in which industries do projects take place?," *Research Policy*, vol. 30, pp. 993-1018, 2001.

[50] Shah, S. K.; "Open beyond software," in *Open Sources 2*, D. Cooper, C. DiBona and M. Stone, Ed. Sebastopol, CA: O'Reilly Media, 2005.

[51] Shah, S. K.; "Motivation, governance, and the viability of hybrid forms in open source software development," *Management Science*, vol. 52, pp. 1000-1014, 2006.

[52] Shirky, C.; "In defense of 'ready, fire, aim'," *Harvard Business Review*, vol., Feb. 2007.

[53] Sourceforge; Retrieved 2/29/08 World Wide Web, www.sourceforge.net.

[54] von Hippel, E.; "Open Source Software projects as user innovation networks," working paper, 2002.

[55] von Hippel, E.; *Democratizing innovation*. Cambridge, Mass.: MIT Press, 2005.

[56] von Hippel, E. and G. von Krogh; "Open source software and the "private-collective" innovation model: Issues for organization science," *Organization Science*, vol. 14, pp. 208-223, 2003.

[57] von Hippel, E. and G. von Krogh; "Free revealing and the private-collective model for innovation incentives," *R&D Management*, vol. 36, pp. 295-306, 2006.

[58] von Krogh, G., S. Spaeth and K. R. Lakhani; "Community, joining, and specialization in open source software innovation: a case study," *Research Policy*, vol. 32, pp. 1217-1241, 2003.

[59] von Krogh, G. and E. von Hippel; "The promise of research on open source software," *Management Science*, vol. 52, pp. 975-983, 2006.

[60] Weber, S.; *The success of Open Source*. Cambridge, London: Harvard University Press, 2004.

[61] Willis, N.; "Lessons learnt from open source Xara's failure", Retrieved 2/29/08 World Wide Web, http://www.linux.com/feature/119790.

[62] Yamagishi, T. and K. S. Cook; "Generalized exchange and social dilemmas," *Social Psychology Quarterly*, vol. 56, pp. 235-248, 1993.