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BENKLER REVISITED – VENTURING BEYOND THE OPEN SOURCE SOFTWARE ARENA?

Completed Research Paper

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Abstract

The organizational principles of open source software (OSS) development have challenged traditional theories in economics, organization research and information systems. In a seminal paper, Benkler (2002) provided a comprehensive framework to structure and explain these OSS principles. Coined Commons-Based Peer Production (CBPP), his framework has inspired a large stream of research on OSS. The objective of our paper is to determine whether CBPP also provides a viable framework to investigate projects of open innovation in non-software related domains. Using a case study approach, we focus on four projects that attempt to operate in line with the OSS phenomenon, but deal with tangible outputs (biotechnology, automobiles, entertainment hardware, and public patent review). We show that in general the CBPP framework is well-suited to explain "open" value creation in these domains. However, we also find several factors which limit its adoption to non-software related arenas.

Keywords: Open innovation, open source software, commons-based peer production, qualitative research

Introduction

The success of open source software (OSS) has challenged traditional principles of common wisdom on how the software market works (von Hippel 2001) and has started a wide debate on the changing role of intellectual property rights (de Laat 2005). From an economic perspective, a large body of scholarly research has focused on the organization of OSS development projects and the motivation of its contributors (Lakhani and von Hippel 2003; Lerner and Tirole 2002 and 2005; Osterloh and Rota 2007; von Krogh et al. 2003). The organization of value creation in OSS projects has changed the way we think about the organization of knowledge production and the division of labor (Giuri et al. 2010). With OSS, a new model of economic production has taken root – one that should not (according to widely held beliefs about economic behavior) even be there.

A central contribution in the literature researching this new economic model of OSS has been a paper by Benkler (2002) in *The Yale Law Journal*. Here, Benkler describes his model of Commons-Based Peer Production (CBPP) that provides a framework to explain some fundamental new methods of coordination and cooperation observed in OSS development. These methods enhance the established framework of institutional economics (Williamson 2000). CBPP implies a unified intellectual work based on self-selected, dislocated volunteer effort and mediated by technology that has neither traditional hierarchical organization modes nor (mostly) financial compensation, as common on a market (Lakhani and Wolf 2005). CBPP is strongly linked with the term "social production" (Benkler

2006). This model contrasts firm production (where a centralized, hierarchical decision process decides what has to be done and by whom) and market-based production (where tagging different prices to different jobs serves as an incentive to anyone interested in doing the job; Williamson 2000). As we will show in more detail in the next section, Benkler's (2002) paper has received the broad attention of scholars in information systems, economics, law, and innovation management. It can be considered as one of the core seminal theoretical papers on OSS development.

According to Benkler, however, the CBPP framework can explain more than just OSS production. It also covers many different types of intellectual output such as internet encyclopedias, online books, news websites and other digital properties (Benkler 2002, 2006). The motivation of our paper builds on this statement. About ten years after the CBPP model was published, we now want to revisit Benkler's paper and his proposition of a broad applicability of CBPP beyond OSS development. Our objective is to test whether CBPP is applicable to non-software arenas, a theme that rarely has been addressed in the literature. We present a multiple case study analysis that looks into the applicability of the CBPP model on "open" development projects in the non-software domains of biotechnology, automobiles, patent review, and IT hardware. Our results highlight that development projects in these domains indeed can be successfully organized according to the open principles of CBPP (e.g. the modularity of tasks). However, we also identify a number of critical factors that limit its applicability to non-software related outputs. These challenges lead to a number of open questions for further research.

Our paper is organized as follows: In the next section we briefly discuss the relevant literature on the organization of OSS development projects and recap Benkler's concept. We then set forth our comparative case study approach and provide an overview of the context of the four cases. After that, the empirical results from the case studies of CBPP in non-software domains are presented. Finally, our findings are discussed in relation to the earlier literature, and implications for theory and practice are derived.

Theoretical and Conceptual Background

Previous Research on Open Source Software (OSS) Development

OSS represents a novel approach for developing computer software (Lakhani and von Hippel 2003; Raymond 2001). Some well-known examples are Apache, Samba, or Linux. The overall goal of these projects is the joint development of software within a group of peers. Although there is a broad scope of OSS projects, the most striking feature of these projects probably is the lack of traditional organizational mechanisms. This is manifested in the absence of conventional hierarchies, rules, and internal organizational bodies (Crowston and Howison 2006; von Krogh et al. 2003). "Open" in general indicates that anyone is permitted to study, change, improve, and distribute the unmodified or modified output (software). The term "open source" denotes a legal agreement that exhibits a variety of differences from conventional approaches. The source code is freely available, a contrast to conventional proprietary solutions. Software developers can alter the source code and redistribute it, an aspect that led Richard Stallman (the founder of the GNU project) to coin the term "copyleft" as an antithesis to *copyright* (de Laat 2005). The only obligation that ensues from the copyleft is to likewise distribute the results under the same conditions. Apart from that, the only rules in place take the form of style guides. Hence, most of the rules are informal in nature and are conveyed in the course of working with fellow developers or by means of official acclamations on the websites that express the rules in a companionable manner.

Apart from the technological and legal infrastructure, OSS projects are also characterized by a set of shared norms, which is why several authors relate to "OSS communities" (O'Mahony 2003). As a result, these projects are not compared to formal organizations, but are viewed as communities of practice (Kogut and Metiu 2001; Lave and Wenger 1991). In addition, no monetary remuneration exists for the participants, who are often highly skilled developers (Raymond 2001). Hence, the motivational mechanisms that explain the voluntary participation of these participants ought to be different (Benabou and Tirole 2003; Lakhani and von Hippel 2003). Referring to the conception of Deci (1971), a dualistic differentiation between intrinsic (i.e. activities and behaviors that participants naturally engage in for their own sake) and extrinsic (i.e. where a direct compensation for the respective activity is anticipated) motivation is proposed.

With regard to intrinsic motivation, contributors to OSS projects often indicate that they just enjoy improving the source code (Lakhani and Wolf 2005). Therefore, innate inspiration seems to be of major importance, as this may

lead to a greater possibility to attain this goal. In a similar vein, it has also been conjectured that these developers will invest a considerable amount of time and effort to refining the software code (Lakhani and von Hippel 2003). Additionally, altruism and pro-social behavior may stimulate further contributions among developers (von Krogh et al. 2003). Closely connected to this is the observation that most software developers are highly idealistic, which is often manifested in an anarchic code of conduct. One main driver of motivation stems from antagonizing capitalism (Lakhani and Wolf 2005).

However, the importance of extrinsic drivers of motivation like personal or future financial rewards has also been shown. For instance, developers might benefit from improvements of the software code that they refined, which represents a personal reward (Lerner and Tirole 2002). In these cases, their expertise comes to the fore in the respective community, whereas the genealogy of thoughts is still accessible within the ‘threads’. Subsequently, other programmers will respond to this question by commenting directly in an evolving list attached to the initial question. Apart from personal benefits, extrinsic motivation is also evoked by social recognition among peers. By frequently updating the source code, participants can enhance their reputation in the respective community, which can be labeled as a form of "self-marketing" or "status signaling" (Jeppesen and Frederiksen 2006).

Commons-Based Peer Production (CBPP)

Analyzing OSS regimes, the organizational efficiency of such projects cannot be described by conventional models of hierarchies, markets or networks (Demil and Lecocq 2006). In this context, Benkler (2002; 2006) proposes his concept of CBPP to elucidate the OSS phenomenon more adequately. He strives to explain the motivation and coordination mechanisms behind the creation of OSS, concentrating upon the Linux operation system. Benkler suggests that OSS developer communities are not based on a discrete allocation of property rights and formal contracts. The software development is rather dominated by self-motivation and self-selection of tasks by the individual participants. Three building blocks of the CBPP framework merit our particular attention, representing the core mechanisms of "peer production": broadcasting of tasks or problems, granularity of the overall development task, and the use of an online platform for coordination and collaboration.

First, tasks are ‘broadcasted’ by individual contributors or a focal coordinating body, that is, public announcements are made inviting participation in the solution to a problem that has been aired (Jeppesen and Lakhani 2010). Potential participants then self-select whether they contribute to the task, to what extent, and with which resources. Those who react to an open call for contributions are motivated by numerous intrinsic and extrinsic motives in comparison to conventional organizational settings, but generally *not* by salaries or hierarchical commands (Lakhani and Wolf 2005; Lerner and Tirole 2002). The economic benefit of such a mechanism is the efficient allocation of ‘open tasks’ to those contributors who either have the lowest cost in solving the respective task (as they e.g. have specific knowledge required to solve the task in advance) or the highest motivational stimuli (e.g. challenge or enjoyment) to work on the task. Studies comparing this ‘broadcasting’ and self-selection approach with conventional methods to organize the division of labor in (for instance, hierarchical) settings illustrate that the CBPP system is often superior in terms of efficiency when compared to the more conventional approaches of labor division (Jeppesen and Lakhani 2010).

Secondly, CBPP demands that a complex problem be separated into smaller modules which can be solved independently of each other. Benkler (2002) calls this the *requirement of granularity*. Smaller modular tasks can be allocated easily to different actors (Baldwin and Clark 2006), which increases the likelihood that a participant has specialized knowledge to solve this particular task. A supporting condition is the scale and scope of the network of contributors: The larger the number of ‘peers’ in the network (participants or contributors) and the more heterogeneous their individual knowledge, the larger the probability that a task will be selected by a participant and solved efficiently. Finally, CBPP demands as an important prerequisite the possibility to operate on online media. Information on the tasks has to be digitalized for easy distribution in the network of dispersed volunteers. Similarly, contributions have to be electronically transmitted back to the seeker for screening, evaluation, and – if approved – integration in the existing product. Without digital media, transaction cost would be prohibitively high for this organizational approach.

In addition to these mechanisms for the organization of the division of labor in a network of peers, the output of their collaboration has to be "commons-based". This term relates to the use of licenses for property rights that do not restrict sharing or the use of created solutions within the network. The output of the peer production process has to be "open", i.e. placed in an information commons allowing anyone to study, use, modify, and distribute the

knowledge placed in these commons. This aspect also makes it easier to re-use existing knowledge for problem solving after a task has been broadcasted into the community (Haefliger et al. 2008). The conditions of using this open information are regulated by a license. In addition to the "copyleft" licenses used for OSS, other types of legal codes also exist for other classes of goods. A broadly used example for such a license is the set of licenses published by the Creative Commons initiative.

CBPP Impact

Benkler's (2002) CBPP framework has been received well by other scholars. To assess its reception in more detail, we conducted a literature search of peer-reviewed publications from the ISI Web of Knowledge (SCI, SSCI) and the Scopus databases. Covering publications until March 2010, we found 150 citations of Benkler's paper (116 scientific articles and 34 conference proceedings) in the field of law (57%), economics (33%), and/or information systems/computer science (16%). More than half of them (53%) have been published within the last four years. We further conducted a Google Scholar citation analysis (using the approach outlined in Harzing and van de Wal 2008) and found 1002 citations of Benkler's paper. This also covered working papers and research reports not yet published as a formal paper. Overall, this analysis confirmed the seminal character of Benkler's contribution. It became a key contribution for the growing body of organizational research on OSS and related phenomena during this period. A search termed "open source software" leads to a total of 1,982 articles and 2,495 contributions in proceedings (according to the ISI Web of Knowledge), of which 355 are in the field of social sciences/economics. For our analysis, we read all 150 peer-reviewed publications referring to Benkler (2002) and conducted a content analysis with regard to the themes addressed. We found that these papers almost exclusively target software related issues. Table 1 presents a closer look at a few papers from top-ranked peer-reviewed journals in management and organizational science. These papers are prototypes of research where CBPP is intensively analyzed and used as a construct for further argumentation (based on ISI Web of Knowledge and Journal Citation Report, JCR).

Author	Journal	Title	Argumentation	Empirical basis	ISI Impact Factor^a	Citations Received^b
Forte et al. (2009)	Journal of Management Information Systems	Decentralization in Wikipedia Governance	Rich descriptions of how various forces produce and regulate social structures at Wikipedia	In-depth interviews with 20 individuals	1.867	/
Haefliger et al. (2008)	Management Science	Code Reuse In Open Source Software	Peer production in OSS development is strongly influenced and driven by code re-use	Qualitative and qualitative data of six OSS projects	2.354	20
Feller et al. (2008)	Information Systems Research	From Peer Production to Productization: A Study of Socially Enabled Business Exchanges in Open Source Service Networks	Extension of CBPP principles in OS Service Networks as an emerging business network archetype	Qualitative case study analysis	2.682	2
Osterloh and Rota (2007)	Research Policy	Open Source Software Development- Just Another Case of Collective Invention?	Role and motivation of contributors within OS self-governance regimes. OSS development is able to solve the social dilemma of rule development and enforcement	Three cases of collective invention	2.655	60

continued on next page

Table 1. Selected high-ranked management contributions building upon Benkler (2002) (Part II)

Author	Journal	Title	Argumentation	Empirical basis	ISI Impact Factor ^a	Citations Received ^b
Baldwin and Clark (2006)	Management Science	The Architecture of Participation: Does Code Architecture Mitigate Free Riding in the OSS Model?	Architecture of OS development process based on implicit exchanges can diminish and destroy profitability of a commercial codebase	None (modeling approach)	2.354	18
Pitt et al. (2006)	Journal of the Academy of Marketing Science	The Penguin's Window: Corporate Brands from an Open-Source Perspective	The OS phenomenon represents a final phase in the evolution of corporate (open) brands.	None (conceptual)	1.289	25
de Laat (2005)	Research Policy	Copyright or Copyleft? An Analysis of Property Regimes for Software Development	Discussion of rights granted to distribute modified code in OS licensing	Literature study	2.655	27

^aAccording to ISI Web of Knowledge ^b Google Scholar analysis (Meho and Yang 2007)

Synthesis and Research Question

Today, we have a deeper understanding of OSS development with regard to issues like community behavior, participant motivation, or governance structures. Benkler's (2002) model of CBPP provides a well-established framework to consolidate these findings. There is, however, only very little research regarding whether these principles also could be transferred to the physical domain in "open" development projects beyond software. This is particularly striking as we are currently faced with a growing body of research on user innovation and the participation of external actors in "open innovation" processes of organizations (e.g. Chesbrough 2003; Faulkner and Runde 2009; Ogawa and Piller 2006; von Hippel 2005). This research is matched by practices in industry which create platforms to collaborate with (communities of) users and other external experts to solve technical problems during the innovation process (Jeppesen and Frederiksen 2005).

At the same time, organizations are inspired by the success of OSS and strive to transfer these principles into other domains (Raasch et al. 2009; Shah 2005). However, there still is not much known about the opportunities, parameters, and barriers of organizing new product or service development according to the principles of OSS. Table 2 provides an overview of the few previous studies that aim to make this transfer. However, an explicit test of Benkler's CBPP framework in domains beyond software has not yet been conducted. Also, the research summarized in Table 2 predominately focuses on non-profit or pre-competitive initiatives outside the conventional area of new product/service development in commercial settings.

The objective of our paper is to investigate the enabling and constraining factors for applying the idea of CBPP to non-software related, commercial arenas. With this research, we also want to provide a critical review of the applicability of Benkler's framework and identify contingencies which influence its application. In short – we want to revisit Benkler's CBPP idea in "open" development projects in diverse fields that took place within the decade after the seminal publication was published. This also will allow us to identify open questions for further research on the organization and governance of "open" development.

Table 2. Existing research analyzing the application of OSS principles beyond the software arena

Author	Cases	Product/service that has been peer-produced in an "open" community	Findings
Raasch et al. (2009)	OScar RepRap OSGV Openmoko Neuos OSD	Car with sustainable mobility concept 3D printer for home use Sport utility vehicle (SUV) Mobile telephone Home entertainment device	OSS development principles feasible for physical products ("open design" and governance of "bazaar structures")
Hope (2008)	Biotech industry	Biotech compounds and analytic methodology	OS biotechnology is both desirable and broadly feasible
Pearce et al. (2005)	Biotech industry	Biotech compounds and analytic methodology	Biological open source licenses (BiOS) are conceivable
Benkler and Nissenbaum (2006)	SETI@home NASA Clickworkers Slashdot.com	Search for extraterrestrial intelligence Classification of Mars's craters User-generated technology news	Narrative evidence of emergence

Research Setting

In order to explore CBPP in the non-software arena, we conducted a number of in-depth case studies of projects in this domain. Given the lack of previous research, a *comparative case study* design was chosen in order to allow for a comparatively broad inquiry of Benkler's idea (Yin 2008). Our research objects claim to operate in line with mechanisms similar to CBPP. More specifically, we selected projects based on a maximum-variation logic used to identify common patterns and differences across cases (Miles and Huberman 1994). This tactic is appropriate to our cases insofar as these projects are interesting due to their considerable differences with one other. Given the explorative nature of the investigation, generalizations are only made with respect to theory. Our cases do not intend to reflect a representative sample of benchmarking practices, but rather act as an illustration of striking examples in order to observe what is happening (Burgoyne and Reynolds 1998). The resulting theoretical contribution is likely to be valid, as it is closely linked to case evidence. There are clearly limitations to this research approach. As with any case study, the findings cannot easily be generalized to other empirical settings. A few general observations about the environment in which these cases act can nevertheless be made, and the approaches we found may work well in another context. The result of this research will be an evidence-based analysis which offers insights into the transferability of the CBPP model.

Data Collection and Analysis

Our research process lasted from 2007 to 2010, and was part of a larger research endeavor to comprehend the way OSS-inspired activities can be conceptualized against the background of Benkler's notions. Unfortunately, there is no comprehensive database or repository of "open" projects beyond the software industry. So our approach was to devote considerable effort to gathering data on possible projects from a wide range of sources like articles, books, press, websites, wikis, etc. The best return revealed a comprehensive "blog research" of frequently updated pertinent web blogs for identification and first exploration of cases. The number of ventures identified that were based on peer production with non-software output is fewer than 50. Furthermore, several initiatives were not successful. We ultimately came up with a final set of about 20 possible cases, from which four were chosen following the criteria outlined in the previous paragraph.

As common in the case study approach, several data collection approaches were used to enable triangulation of evidence and increase construct validity (Miles and Huberman 1984; Yin 2008). As for gathering data, an extensive pre-study was first done where we screened the field and collected data from multiple cases, finally narrowing it down to four cases which are described in Table 3. Secondly, we conducted a content analysis of the websites, annual reports, company directories, business and specialist press from the different projects, as well as publications related to them in scientific journals and practitioner outlets. This information was used to obtain an idea of the

environment and important milestones. It formed a useful background for later steps and provided us with the possibility of comparison with other data sources. Third, semi-structured face-to-face interviews were conducted with the project participants (18), exclusively focusing upon those aspects that remained to be understood with regard to the overall research questions. Two pilot interviews were carried out beforehand to learn how to use the interview manual and test the relevance of the questions. In conducting the data analysis, we transcribed the interviews. This phase was subsequently supported by the use of "atlas.ti", a software application for the analysis of qualitative data. In order to heighten the overall quality of the data, the authors of this research reread the relevant transcripts and discussed the content, only incorporating those aspects that were agreed upon. The different data sources allowed us to form case studies for each one of the individual projects, which thereafter were compared to observe similarities and differences (Eisenhardt 1989).

Brief Description of the Projects

We analyzed four projects operating in the CBPP mindset. These cases depict a triad that identifies the model in the profit sector as a business strategy of a market-orientated enterprise (Bug Labs, OScar), as a non-profit sector environment (BiOS), or as a public sector agency (Peer-to-Patent). Table 3 provides some background information about the projects. More information on their background and motivation is provided in the following to understand the nature of the business and the organizational context.

<i>Project</i>	BiOS	Bug Labs	OScar	Peer-to-Patent
<i>Objective</i>	Creation of a science commons of basic tools and gene sequences for biotechnology research	Providing adaptable and customizable consumer electronics	Development of a sustainable and affordable automobile	Public co-production of patents together with USPTO civil servants
<i>Time</i>	2004 - 2008	2007 - present	1999-2004 and 2005-present (relaunch)	2007-2009
<i>Country</i>	Australia	USA	Germany	USA
<i>Output / Product</i>	Biological, agricultural and biotechnology science	Applications used for BUG device constituting a novel product	Automobile	High-quality examinations of pending patents supporting patent examiners
<i>Nature of project</i>	Non-profit	For-profit	Non-profit	Public
<i>Nature of the final product</i>	Virtual / intangible (research results under BiOS license) and tangible (tools, genetic sequences, samples)	Tangible (hardware configuration) and intangible (applications)	Tangible	Virtual / intangible (improved review process)
<i>Number of contributors</i>	> 300,000	>1400 users in BUG Labs community	Approximately 100	> 2,700 reviewers
<i>Owner/Funding</i>	Richard Jefferson / Rockefeller Foundation and other donors	Peter Semmelhack / Union Square Ventures (venture capital)	Markus Merz / the funding is ensured by the core team	Omidyar Network and MacArthur Foundation (funding project platform and operating costs)
<i>Similar projects</i>	OneWorld Health, The HapMap Project, The Human Genome Project, Collaborative Drug Discovery	OpenMoko (mobile phone), VIA OpenBook (notebook), Lego Mindstorms (toys)	Open Source Green Vehicle Project, Local Motors, FiatMio	IP.Com, PatentDebate, PatentFizz

BiOS: The BiOS initiative originated in 2004 at CAMBIA, an Australian biotechnology research institute. The institute is led by its founder, Richard Jefferson. Apart from Jefferson, the institute has 25 employees, including Ph.D. students and visiting researchers. According to its homepage (bios.net), the objective of BiOS is to "democratize problem solving to enable diverse solutions through decentralized innovation" in the field of biotechnology, encompassing among others, plant and animal breeding, medical and public health interventions, or genetic improvements. This assumption is based on the observation that disadvantaged communities suffer from nutritional deficiencies, food shortages, and related maladies. Thus, the central concern of BiOS is to empower disadvantaged communities to become innovators on their own. This is achieved by means of developing novel technologies and tools and providing them under an open license to a science commons.

Bug Labs was founded by Software specialist Peter Semmelhack and supported by venture capital seeding in 2007. As a New Yorker, in the immediate aftermath of 9/11, Semmelhack found himself wanting to know the physical location of his wife and child. His aim was thus to build a GPS tracker, allowing him to monitor his family on a website. When he found neither a device that did the job, nor a platform he could build on, the idea of the "Bug" was born, a combination of a hardware and software platform. Customers purchase a "BUGbase" (the core CPU) and may then freely and easily design software for this personalized mobile device (Gibb 2009). Complete with all the abilities of a PC, the Bug allows computing enthusiasts to create a device with their own specifications in mind. Moreover, different hardware modules like a touch screen LCD, a GPS Receiver, a USB connector, or a motion detector can be added to the Bug base. Bug's design was inspired by Lego bricks. Users should be able to snap pieces on and off without worrying about the device freezing up, and the pieces should be attractive and fun to work with. On its development platform (buglabs.net), users can create, upload and download applications for these components, and engage in exchange on forums, wikis and tutorials.

Oscar: This project was founded by a former employee of a European car manufacturer, Markus Merz, in 1999. His objective was to develop a car according to the principles of OSS. In contrast to the IP regime that prevails in the traditional for-profit oriented automotive industry, participants had the incentive of patent-free collaboration. This aimed to allow for a collaborative space that cannot be achieved or offered by conventional car manufacturers. Merz installed a public internet platform (www.theoscarproject.org) where volunteers can enroll and engage in discussions and add their own contributions to foster the development of the car. This assertion is also officially stated in the so-called "Oscar Manifesto" on the project's homepage. A wave of initial enthusiasm surrounded the project. However, activity diminished substantially in 2001. Merz managed to revive the project in 2005. Since this time, a core team of four people and around 100 enthusiasts have been engaged in the project (who all have posted at least one substantial contribution). From these 100 participants, 15 are very active, i.e. they have submitted high double-digit numbers of entries.

Peer-to-Patent, launched in 2007, is a pilot project in collaboration with the United States Patent and Trademark Office (USPTO), motivated by a backlog of about 800,000 US patent applications in 2007. It focused on helping patent examiners to perform high-quality examinations of pending patent applications by enlisting the public to identify prior art. A US patent examiner typically has only 20 hours to evaluate an application (Katsh and Noveck 2007). The idea of Peer-to-Patent is that volunteers can pick applications in their domain of expertise and report prior art references within existing patent applications (in the field of computer architecture, software and business methods). This helps the examiners to focus their attention on the submissions of prior art that have the highest relevance to an application (Center for Patent Innovations 2009). Major companies such as IBM, Microsoft, Hewlett-Packard, Intel, or GE have submitted patent applications to the Peer-to-Patent process, asking for a public and collaborative patent review process.

Analysis of the Cases

In this section, we elucidate the results of our comparative case study. Given the space constraints of this paper, some basic characteristics of the projects and their achievements are presented in the form of a table that also comments on some of the major challenges experienced in each case (Table 4). In the following paragraphs, we will comment on some specific observations of the cases in more detail.

The *BiOS* project was initiated by a large for-profit corporation with the objective of preventing the exclusive ownership of basic tools and genetic sequences which could become the foundation for many applications and medical treatments. The thinking was that scientists should place their developments in a science commons by using an open license (copyleft). Regarding the results that have been provided by the community in this manner in the

BiOS project, we clearly can state that the project has been able to assemble a large commons of research results by numerous contributors. These biotechnological results are also presented online, which is in line with previous OSS research. The project hence illustrates the "commons based" aspect of Benkler's CBPP framework. However, the coordination mechanisms to organize the production of this knowledge have not been central for this initiative. Much of the information provided by contributors to the BiOS commons has been created in the conventional governance structures of a scientific lab. Looking closer at the mechanisms of using the information in the biotech commons, some challenges become obvious, resulting from the physical nature of biotech equipment and organisms. The transfer of the "copyleft principle" of OSS is not easily applicable to the biotechnological realm. For instance, this arena is heavily regulated by both national and international law. Therefore, the transferability of information is partially restricted. In addition, transporting real-life specimens is not possible for all areas in the life sciences. In contrast to OSS where code lines are refined, the final product in the case of BiOS needs to be put into practice by means of creating and utilizing physical artifacts, which are complex and costly to organize. In addition, the BiOS project also demonstrated that the maintenance of an online platform and the remuneration of staff require funding. BiOS has been dependent upon external grants and donors for this purpose. When funding ceased, the project had to be re-integrated into the enterprise of its initiator. This demonstrates one of the restrictions of transferring the CBPP idea into the physical domain.

Bug Labs can be seen as a new business model for hardware based on open source principles. The company is clearly profiting by organizing its development processes according to the CBPP framework. The collaboration of various dislocated and intrinsically motivated participants allows the company to offer a wide spectrum of applications with just a few in-house developers and no need to engage in formal contract research. Users e.g. have realized that the Bug is well-suited for mobile consumer usage, and also as a steering unit for robot developers and embedded system builders. Bug Labs' vision of moving hardware development and production away from a small number of companies building gadgets for millions, to thousands of innovators creating devices for rather small niches fundamentally builds on the application of the CBPP framework in this industry. The core enabling principle is the innovative modular design of the Bug and its additional components. This granularity of the hardware allows users to design their own electronics and individually customize them, share problems on the project platform, and collaborate in solving these tasks. Currently, 182 apps are available (some of them have been downloaded several thousands of times), offered by a community of more than 1400 registered users who also provide support in the forum.

While the *OScar* project has managed to attract approximately 100 enthusiasts that engage in the development and design of the car, it can be regarded as the least successful example in our sample. The modularity of the tasks is deemed essential for the operation of the project, and the contributors stated recurrently that they need a modular structure in order to simultaneously develop the project through separate initiatives. But creating the modular structure for a complex system like a car repeatedly proved to be difficult. In addition, automotive development demands rather sophisticated simulation equipment for virtual testing, which at some point also has to be done with real prototypes. Organizing these capabilities is costly and know-how intensive. Nevertheless, the project demonstrated that for concept-focused tasks, open collaboration was possible and fruitful.

Peer-to-Patent reveals how broadcasting patent applications for open review can create a model for participatory administration and improve administrative processes with regard to quality and speed. Those who respond to a specific Peer-to-Patent open call are self-selecting volunteers, bringing along enthusiasm and expertise in one particular field. Contributors research the application, upload relevant publications, give suggestions for further research for use by the patent examiner or give comments on the relevance of submitted pieces of prior art. Following online discussions, each team vets the submissions made by its members. The group votes on which ten submissions are most relevant. These are then forwarded to the Patent Office (Noveck 2009). Data from the two-year pilot phase show that an open network of reviewers is willing to volunteer time and improve the quality of information available to patent examiners, and that such citizen peer reviewers are capable of producing information relevant to the patent examination process. Peer-to-Patent attracted more than 74,000 visitors and 2,600 registered peer reviewers (71% holding a Masters or Ph.D. degree). On average, a reviewer contributed six hours of time to each application. Participants from 151 countries submitted 390 references to prior art on 187 applications. In a survey conducted at the end of the pilot stage, 75% percent of reviewers thought that a third-party submission of prior art should be incorporated into regular USPTO practice, while 69% percent of examiners felt that a program like Peer-to-Patent would be useful if incorporated into regular office practice (Center for Patent Innovations 2009). 12% of participating examiners stated that prior art submitted by the Peer-to-Patent community was inaccessible by the USPTO.

Table 4. Results of case projects

Results	BiOS	Bug Labs	Oscar	Peer-to-Patent
<i>Realized Result / Output (as of April 2010 / end of project)</i>	Patent data base (10,162,293 patent documents), sharing life science ideas in an online forum	Applications used on BUG device (currently 182 apps available)	Approx. 50 different advanced design studies	390 references to prior art on 187 applications
<i>Efficiency / Benefit to community</i>	Open access to biotechnological innovation and patents	Collective development of electronic products for highly specialized niche applications	Collaborative development of automobile with specific requirements	Faster patent review process and increased patent-to-market
<i>Innovativeness of contributions</i>	High	Medium-high (novel home entertainment applications)	Medium-high (task dependent, can be simple suggestions, but also sophisticated innovative solutions)	Low (identification of prior art), but often not known to professional examiner
<i>CBPP principles:</i> (1) <i>Information commons</i> (2) <i>Broadcasting of tasks</i> (3) <i>Granularity of tasks</i> (4) <i>Dedicated online platform</i>	(1) Given and core idea of project (2) Given in forum, but not core interest of project (3) n.a. (4) Given and core success factor	(1) Given (2) Given (3) Core idea of new hardware design (4) Given	(1) Given (2) Given (3) Constraining factor (4) Given, but constraining factor	(1) n.a. (2) Given and core idea of project; realized both with regard to problem solving and quality control (3) Given (4) Given
<i>Outcome</i>	<ul style="list-style-type: none"> Patent data base for sharing biotech-related information on basic tools and genetic sequences Making technological innovation and solutions available on a global scale, in particular for disadvantaged communities 	<ul style="list-style-type: none"> Highly specialized innovation of consumer electronics for niche markets Use of OSS to build new products instead of designing new hardware and printing circuits New and user-driven business model by selling BUG devices as a basis for user-hardware-creation 	<ul style="list-style-type: none"> Basic requirements of car were agreed upon (gathered by the volunteers participating in the Oscar project) Development of a collaborative car design in a modular fashion Advanced concepts for further refinement and combination 	<ul style="list-style-type: none"> Patent examiners gain more and better information Innovators will have greater certainty about quality of patents in their domain Reduction in low-quality patents might lead to reduction of costly litigation, unnecessary licenses, and market disruption
<i>Managerial challenges</i>	<ul style="list-style-type: none"> Cost intensive production / test phases External funding required to run project platform Legal restrictions regarding the usage of specimen Different national requirements regarding the need for documentation Securing the project against misuse 	<ul style="list-style-type: none"> Demands initial investment and effort to build corresponding modular hardware (organized conventionally in a firm hierarchy) Expanding size of community Difficult control of product development as based on individual need-driven effort 	<ul style="list-style-type: none"> Granularity of overall problem difficult to achieve without hierarchy Legal regulations restrict development Need for substantial funding to develop and test prototypes Maintaining sense of community as different designs imply different developments 	<ul style="list-style-type: none"> Organization of in-side-out process of administrative data (patent application) Resistance of public servants to input from external community

Discussion and Implications

In this section, we discuss the results of our comparative case study from the perspective of Benkler's CBPP framework and compare the projects with the OSS arena, identifying enabling and constraining factors. Afterwards, we will conclude with some managerial and general policy implications resulting from our findings.

Theoretical Implications

As a result of our analysis, we were able to identify a number of parallels between the organization and governance of OSS development and the open development of non-software related products in our cases. These factors also illustrate the applicability and transferability of Benkler's CBPP framework.

(1) The *granularity of the tasks* has been essential to the operation of the four projects as well. CBPP will not create any genuinely new things unless people know what is being asked of them. Users of e.g. Wikipedia know what to do because they understand what it means to write an entry for a dictionary. People share a common image of this collective goal (Novek 2009). As a result, a modular task design is likely to be an important feature for the success of any project based on CBPP. In our cases, the respondents provided clear evidence of the importance of this aspect. Whereas tasks at Wikipedia are almost modular by nature (and the same is true of patent applications), granularity represents a more significant challenge for the development of a car or a communication device. In the case of OScar, the contributors repeatedly stated that they need a better modular structure in order to develop the project simultaneously through separate initiatives. This aspect also is reflected in the few formal dimensions that guided the development of OScar: Among detailed technical guidelines, the car was required to be simple, sturdy, easily maintainable, and modular. However, as seen above, realizing modular architecture is a demanding task that often cannot be organized in a collaborative open structure, but demands a more hierarchical organization instead.

In general, modularity might serve as an overarching principle for managing open development in order to coordinate locally dispersed contributors responding to a call for collaboration. We found that the activity itself of phrasing and verbalizing specific problems brings the project forward – especially if the community suffers from a lack of size or commitment to coordinate these tasks itself. However, we are not exclusively advocating modularity, as it might also have detrimental effects. For instance, participation might be restrained if tasks are too narrowly defined and leave no room for creativity. One solution might be to define the interfaces beforehand as accurately as possible to prevent stifling creativity and motivation. Moreover, broadcasted participation and non-supervised division of work might result in a duplication of work and/or fragmented parallel development efforts, which represents a serious challenge in other arenas. Although OSS projects appear to operate unhindered despite this hurdle, tangible non-software operations might seriously be affected by this as it contradicts current management convictions, e.g. lean and just-in-time management. This is an area where further research is required.

(2) Our research confirms that the use of *open license agreements* and the provision of previous knowledge in an information commons provide a crucial underpinning of open collaboration. The commons governs IP and defines rights of usage, modification, and redistribution (Raasch et al. 2009). However, the more sophisticated and the more IP-prone these innovations are with respect to the for-profit arena, the more difficult it becomes to operate on an open license basis. This can be traced back to legal restrictions, e.g. for the case of BiOS with regard to in vivo specimen or the case of Oscar with respect to safety and usability requirements of national registration authorities.

(3) The existence of *extrinsic and intrinsic motivational stimuli* is the bottom line for the success of a project, regardless of whether for software or non-software projects. Low opportunity cost in terms of contributing to the project is an important extrinsic stimulus, as one only needs to have online access to be able to contribute to a platform and offer knowledge and expertise. In the Peer-to-Patent case, for instance, many participants belonged to big companies who had an interest in keeping the quality of their patents high. Their motivation was clearly focused on extrinsic motives. Our interviewees, however, also stated that the aspiration to learn was an important driver to contribute as well. Reviewing a patent application and searching for prior art often extends the individual knowledge stock of the contributor. Similarly, engaging in the OScar project was considered to be beneficial due to the opportunity for learning and developing novel skills and technical insights. This is predominantly based on the assumption that learning is deemed a collective accomplishment. As for intrinsic motivational stimuli, OScar members claimed that they considered working for the project to be a creative pleasure, because participants feel challenged by demanding tasks that match their respective skills. In terms of intrinsic motivational stimuli, writing an app in the Bug Labs domain can be considered a form of creative enjoyment. Several notions, not only those

stemming from the field of OSS, confirm this assumption (Jeppesen and Frederiksen 2006; Mathwick et al. 2008; Raymond 2001). Furthermore, in the case of OSscar, working on the car's aesthetics was an important driver. Although the OSscar automobile until today can only be experienced via the developers' screens, interior and personal aesthetic experiences are likely to be evoked by novel designs.

But contributions from the community also constitute extrinsic motivation. The Bug Labs case, for example, indicates that individual contributors see receiving feedback (directly or in the form of downloaded apps) as being highly beneficial. Moreover, it enables the contributor to satisfy his/her own needs by developing a certain feature for the Bug device which is then revealed freely on the platform (von Hippel and von Krogh 2006). In this context, altruistic persons seem to derive benefits from helping fellow users. This is part of what has been deemed the online 'gift economy' (Malinowski 1922), which alludes to the fact that people give away goods or presents for free in order to establish or maintain social bonds (Mathwick et al. 2008). A sense of belonging to a certain community can be identified as another intrinsic motivation. For online communities, McArthur and Bruza (2001) coined the term 'endoxa', alluding to the feeling of belonging to a community in an online environment. Related to the sense of belonging is the commonly assumed fight against commercial and entrepreneurial ventures, and probably enhancing the common good in the public administration case of Peer-to-Patent. Because of members' shared interests and objectives, the cohesiveness of the community is likely to be intense. Perhaps the most important driver of extrinsic motivation in the OSscar project is the shared objective of developing a pioneering and sustainable car. This aspect was not only frequently mentioned by our respondents, but was also highlighted in the respective forums and the OSscar manifesto. Closely related is the intention to establish a community that incorporates people who share a common interest (Lave and Wenger 1991). In contrast to the patent-dominated IP regime that prevails in the automotive sector, OSscar participants were also motivated by the opportunity of a patent-free collaboration.

Managerial Implications

Our research supports our thesis that the principles of CBPP can be applied to the field of non-software production. We see that self-selected, self-motivated and self-coordinated peers can generate value, illustrated in the design of a car (OSscar), the development of biotechnical solutions (BiOs), the enhancement of a public administration process (Peer-to-Patent), or the creation of electronic devices (Bug Labs). In the following, we want to present some supporting and constraining aspects with consequences for the management of such projects.

(1) The *technological platform* seems to be of utmost importance in every open development venture. It served as the main infrastructure in all projects. Its purpose is far beyond organizing technical communication and exchange of information. For instance, the ability to respond to someone else's ideas was an important feature that enabled mutual exchange in all four of the projects. It served as a central tool to organize the distributed labor of the participants by facilitating exchange of information, broadcasting tasks, providing access to existing knowledge, and serving as the platform to reintegrate the contributions. This observation is in line with related research that stresses the need for such a fleet-footed infrastructure in order to allow frequent exchange of information (Nielsen and Loranger 2006). In OSS environments, big platforms like sourceforge.net or eclipse.org facilitate the exchange of source code and guidance (von Hippel and von Krogh 2003; West 2003). We have seen e.g. in the case of Bug Labs that an easy-to-use platform invites the commitment of contributors and underlines the explicit open call for participation, especially if supported by rich social web tools. While there has been some research on the design for such a platform in the context of OSS, we are not aware of any dedicated research on the design of such a platform for tangible goods. Also, there is no equivalent to Sourceforge for non-software projects. This may be one hurdle for a broader diffusion of the idea of open hardware.

(2) *Code of conduct*: An increasing number of for-profit corporations are currently successfully engaging in activities that integrate input from other companies as well as customers or (lead) users into the innovation process (Chesbrough 2003; Piller and Walcher 2006). These companies may want to go a step further by engaging in additional modes of collaboration, as represented by peer production (Müller-Seitz and Reger 2009). The case of Bug Labs indicates that an entire business model can be built upon selling electronic gadgets with rigorous open interfaces, allowing peers to create apps and thereby define the final use of the device. More research is required to find out what makes communities apply for-profit organizations in the described governance modes and how to operate and incentivize their members in a project controlled by a for-profit company. For instance, a large multinational automotive company attempted to engage in the OSscar project. Once the offer became public within the OSscar community, conflicts ensued and the company had to withdraw from the project – even though this company probably could have provided some of the financial, technical, and coordination support that was lacking.

The major reason for rejection was the aversion of the OSS-inspired contributors towards collaborating with a for-profit corporation. Hence, being vigilant about the code of conduct in individual communities, as well as considering the dangers, are important actions that management needs to consider when it comes to deciding if or where a company ought to engage. Consider Apple's iTunes platform as an alternative to Bug Labs, offering thousands of applications for the iPhone. Apple has attracted dislocated software developers with a model where commercial (not commons-based) peer production combined with financial reward for apps constitutes a successful hybrid business model with a moderate level of openness. In this emerging area, much more research concerning success factors, motivational stimuli, and modes of governance is required.

(3) *Participant communities*: OSS developers appear to represent a comparatively homogenous community, or rather, appear to exchange rather homogenous content (e.g. source code of advanced language, classes, libraries, etc.). In contrast, collaborating on physical products often demands that contributors have a background in diverse professions such as engineering, design, management, or the environmental sciences. At any one given time, they can be working on an object, i.e. an automobile, while operating with different codifications (CAD plots, pictorial designs, calculations, etc.). As we could observe in the OScar case, the challenge to design some innovative details of the car was highly rewarding for both mechanical engineers and car enthusiasts with an economics background. Participants also reported to have benefitted from and enjoyed the broad scope of backgrounds in the developer community. This aspect also was visible at Peer-to-Patent, where contributors held a very wide range of occupations. In this case, heterogeneity also served as an important driver of complementarity for creating the solution. Although the homogeneity of OSS developer communities might explain a part of their appeal, for constructing complex tangible outputs, a heterogeneous group of actors often seems to be required (Jeppesen and Lakhani 2010). This, however, also represents a challenge. In the case of OScar, heterogeneous contributors have different beliefs on how to proceed with the project – similar to a conventional automotive company where the mindsets of R&D and those engaged in the design of the car often differ substantially. The "lack of fiat" (Williamson 2000) in our case studies sometimes resulted in lengthy and unproductive discussions. Another conundrum concerns the motivation of the volunteers. In the for-profit arena, employees are used to being remunerated for their work. On the other hand, pursuing 'voluntary' projects is either to be done in the employees' spare time (which appears questionable in terms of business ethics) or as part of their work (which implies that employees are remunerated, which may make some of the principles of CBPP and OSS obsolete). Managing these trade-offs becomes one of the core challenges for managers engaging in open development projects.

Policy Implications

It still is too early to evaluate the long-term success of CBPP for non-software development. But the current emergence of successful business models incorporating Benkler's principles suggests that – under specific conditions – this model of collaboration may offer advantages over conventional modes of organizing developmental activities. This particularly holds true with regard to knowledge production costs by leveraging the access to external knowledge both with a large scope and at a low cost (Raasch et al. 2009). However, organizations relying on such a production model have to be aware that connecting contributions from this kind of origin with the classical mindset of in-house production may become difficult. Here, a company that already has developed a mentality of open innovation or customer centricity may certainly have advantages. In those cases, however, where the corporate culture tends to focus inwards, pursuing a CBPP strategy might possibly be ineffective due to internal resistance and a lack of absorptive capacity (Cohen and Levinthal 1990).

The Peer-to-Patent case allowed us to extend this discussion from the private to the public sector. Governments have just started to recognize the opportunities of openness and cooperating beyond institutionalized centers of expertise. The case elucidates that decision making (e.g. granting a patent) in the classical way is done with the implication that a civil servant can do it best. Public agencies, however, make decisions every day without access to the best information or without the time to make sense of the data they obtain. With the speed of patent examination out of sync with the pace of entrepreneurial innovation, firms are forced to wait increasingly longer for patents, and licensing strategies can even turn out to be invalid (Kao 2007). While public participation traditionally focused on deliberation, new ways of peer-production can solve an organizational information deficit, gathering and evaluating information and transforming raw data into useful knowledge (Noveck 2009). In this context, the collaborative model of Peer-to-Patent describes the design of a new relationship between a government and its people. Such 'Citizensourcing' transfers the CBPP principle of broadcast search by taking a task that traditionally has been performed by a designated public agent and outsourcing it to an undefined, generally large group of citizens in the

form of an open call. This approach may offer new ways of public value creation by systematically integrating external actors into administrative processes.

Collaborative government is a new model to improve outcomes by soliciting expertise from self-selected peers working together as groups in open networks. By lending their expertise and enthusiasm, volunteer experts can augment the know-how of full-time professionals and coordinate their own strategies, soliciting participation in governance. By taking advantage of cost saving in technology, hierarchies can be transformed into collaborative knowledge ecosystems and radically change the culture of government from one of centralized expertise to one in which the public and private sector (organizations and individuals) solve common (social) problems collectively. The future of public institutions demands a collaborative ecosystem with numerous opportunities for those with the expertise to engage. Such increased responsiveness is especially attainable in all public proceedings where external knowledge, traditional feedback cycles, and public hearings are required by law. With open and peer involvement, the opportunity to enter a caveat or make comments is far more distinctive and may accelerate all kinds of applications and legal actions (Noveck 2009). Far from being unique to the patent system, the lessons learned from soliciting far-flung, self-identifying expertise to improve government decision making can be applied to a broad range of environmental, educational, and other policy domains to solve problems more efficiently (Brabham 2009).

Conclusion

We consider Benkler's (2002) CBPP framework as one of the most fascinating constructs emerging in organizational research in this decade. It not only provides a mindset for understanding the principles of OSS development, but also can serve as a guideline for re-organizing value creation in other sectors. The evident success of OSS has inspired the notion of "open innovation" that strives to realize the potential of external volunteers analyzing modes of co-creation or making use of innovation communities (Piller and Walcher 2006). While a number of papers draw on Benkler's model to depict and explain different aspects of OSS creation, little was known on the transferability of CBPP to the non-software arena. In this paper, we demonstrated that CBPP indeed can serve as a viable framework for the development of tangible products in diverse sectors. We demonstrated the applicability of problem solving and knowledge production organized according to CBPP to improve on a glaring organizational information problem (e.g. at the USPTO) or to support a business model with commercial exploitation (e.g. Bug Labs and BiOS). By selecting cases in the triad of a business case (Bug Labs), a public project (Peer-to-Patent), and self-governed, non-profit projects (BiOS and OSscar), our intention was not just to validate Benkler's framework in a different setting, but also to inspire new research in the field.

However, to generalize our findings, more validation by large-scale empirical investigation is clearly required. Growing practical experiences will offer insights even into unsuccessful projects that disappear from the scene rapidly, revealing factors of failure and hindrances of transferability. Future research also is needed to examine community-level factors that might influence the contributors' sustained participation by studying and comparing multiple communities of software and non-software arrangements simultaneously. Moreover, examining the moderating effect of license agreements and the copyleft philosophy on the contributor's efforts may offer further insights into the governance structure required for a successful project. Finally, the broader empirical investigation of the preconditions under which CBPP is conceivable and convertible into new product development of firms and R&D labs remains uncharted territory and offers fruitful ground for future research.

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