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Beldiman, Dana

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By Dana Beldiman*

Many believe that open source innovation works "faster, better and cheaper" than conventional, proprietary innovation. The success of open source innovation has been seen primarily in open source software (OSS), whose output is an intangible, digital product (bits). This paper asks whether the success of OSS can be replicated in an open source hardware (OSH) environment, which involves tangible products (atoms). Specifically, it considers whether the tangible nature of OSH products presents legal or practical obstacles to their successful commercial implementation, in an environment where no appropriable IP rights exist. To answer these questions, the paper follows the innovation knowledge flow generated by an OSH invention and examines the legal structure and enforceability of open hardware license. It further considers in what way the absence of IP rights impacts the choice of a business model for OSH.

Review of OSS business models indicate that, despite the non-appropriability of IP, software products are being produced through a wide range of models, from pure open source, to hybrid operations, driven by large commercial firms. Hardware presents a more difficult business case than software, because the output of OSH is a tangible product. Implementation of the invention into an end-product requires materials, manufacturing, labor, distribution, etc., all of which are cost-intensive and require capital investment. Nonetheless, a few OSH initiatives successfully run self-funded or non-profit-funded operations, even absent exclusive IP rights. However, given the costs associated with producing a tangible product, future business models are more likely to be a hybrid between open source community and a

*Dr. Dana Beldiman is a professor of law and teaches IP law at UC Hastings College of the Law, San Francisco, USA and at Bucerius Law School, Hamburg, Germany. Ms. Beldiman is the Founder and Academic Director of the Bucerius IP Center. Ms. Beldiman has received legal education in both the US and Germany. In addition to her academic activities, she is a partner with the San Francisco office of Squire, Patton, Boggs, where she practices primarily IP law and IP-related international transactions.

commercial operator. Still, such operations would rely heavily on innovative input from the open source community.

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INTRODUCTION AND OVERVIEW

Many believe that open source innovation works "faster, better and cheaper" than conventional, proprietary innovation. The success of open source innovation has been seen primarily in open source software (OSS), whose output is an intangible, digital product (bits). This paper asks whether the success of OSS can be replicated in an open source hardware (OSH) environment, where the output is a tangible product (atoms). Specifically, it considers whether the tangible nature of OSH products presents legal or practical obstacles to their successful commercial implementation.

Open source community innovation has been extremely successful due to the number of contributors and the speed of innovation. It brings together large numbers of individuals who collaborate and use their minds in solving specific problems. This innovation process tends to occur at higher speeds and generate better performance than most proprietary innovation.

During its relatively short existence, open source community innovation has grown from software to other information products, such as Wikipedia, video journalism, and open science. More recently it has expanded beyond pure information products into the realm of tangibles. "Open source hardware" (OSH) uses the same innovation mechanism as OSS, but its final product is a physical three-dimensional artifact. Products of the OSH process include electronic devices, medical prosthetics, diagnostic equipment, musical equipment, power supply, lab equipment, toys and games,[1] etc.

Because of its fairly incipient state of development, OSH presents the researcher with a fertile petri dish of unsolved questions at the intersection of law, economics, business, and sociology, which raise cross-disciplinary issues, such as appropriability of knowledge, ability to capture value absent IP rights and the relation between an inventive open community and a commercial operator.[2]

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[1] LOCAL MOTORS, https://localmotors.com/ (last visited Nov. 5, 2018) (vehicles); OPEN SOURCE ECOLOGY, https://www.opensourceecology.org/ (last visited Nov. 5, 2018) (agricultural implements); ALEPH OBJECTS, INC. 3D PRINTER https://www.alephobjects.com/ (3D printers); ARDUINO, https://www.arduino.cc/ (last visited Nov. 5, 2018) (circuit boards).

[2] This article provides a "horizontal" overview over the implications of the tangible nature of the OSH product. The numerous legal issues surrounding OSH have been merely hinted on. Further in-depth "vertical" work remains to be done on these issues, to shed light on a variety of innovation-related topics, such as the role of knowledge in innovation, the flow of knowledge between inventor and implementer, managing the inventor community to generate a sustainable stream of innovation, the roles of IP rights and of latent community knowledge, or legal aspects of the OSH license enforceability, in particular relating to 3D printed products. A scholarly perspective on these issues may help validate the OSH industry and stimulate its development.

This paper is intended as an overview over the OSH process, highlighting legal and business aspects in an open community environment, specifically focusing on OSH and the tangible nature of its output. It is structured in three general parts. We first compare OSH to OSS in terms of the knowledge flow [3] enabled by the open innovation mechanism. Next, we consider the legal structure of the open licenses and assess the enforceability of the OSH license compared to the OSH license. The final part discusses the tangible nature of the OSH product, compared to the intangible output of OSS. It inquires to what extent the cost associated with producing a tangible product, combined with the absence of appropriable IP rights, may detract from the commercial implementability of OSH inventions.

The strength of open communities, whether OSS or OSH, lies in their flow of knowledge: early, repeated disclosures of knowledge, lead to its wide diffusion and reuse by a potentially large number of downstream community members and gives rise to an overall enhanced innovation power. However, the trade-off for this wide diffusion of knowledge is a reduction in the incentive to invest. This may make the final (commercial) implementation of the product problematic. We next consider the structure of the OSH license, whose function it is to formalize the diffusion of knowledge that occurs at the creative level, into an allocation of IP rights. We note that the tangible nature of the OSH output prompts a slightly different license structure compared to the OSS license. Its enforceability therefore raises some questions. Finally, we compare the paths toward implementation of the final product. This area presents the greatest difference between OSH and OSS. While software is self-executing, the instructions for its implementation are incorporated into the code and running the program is all that is required, hardware must be built. This involves materials, manufacturing, labor, etc., all of which are cost-intensive and demand capital investment. In general, capital investment requires appropriable IP rights, however such rights are not available under the open source license.

Nonetheless, in the OSH community, inventors have started productizing their inventions, without the benefit of outside investment. These initiatives appear to be successful to some extent, even absent exclusive IP rights, as they derive some competitive

[3] This paper will take a "knowledge-centric" approach. The term "knowledge" has been borrowed from economic literature to broadly denote information resources of any type, including data, code, scientific formulas, test results, designs, know-how, text, etc.

advantage from the latent knowledge that resides within the community. However, because of the cost associated with production of a tangible good, OSH operations may only be able to scale if outside funding by a commercial entity is available. A hybrid model that combines an open community with a commercial operator would continue to heavily rely on the community as a source of continuing innovation. At the same time, a misalignment in ethos and values exists between the open source community and the commercial operator. To ensure the continued flow of innovation, the relationship between the two groups must be managed with skill in order not to destabilize the community.

I. THE CHARACTERISTICS OF OPEN SOURCE INNOVATION

A. Background of collaborative (open source) innovation

Collaborative innovation[4], based on early cumulative disclosure of non-appropriated innovation, has been extensively described in scholarly literature.[5]

The earliest and most prominent example of such innovation is Open Source Software (OSS). OSS's emergence has been enabled by the digitized network environment. Because of low communication costs, the collaboration on shared innovation projects has become possible among geographically dispersed individuals. They form communities, most often of users, for purposes of common problem-solving projects and contribute time, knowledge and skill, generally, for free.[6] Participants join based on a combination of intrinsic non-monetary motivations, such as the desire to exercise creativity, the desire to overcome a challenge, the sense of achievement having solved a problem, identification with a particular group or altruism.[7]

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[4] Various forms of collaborative innovation are referred to as peer production, user innovation, open (source) innovation or co-creation, respectively. The form at issue here is characterized by the fact that the rights to any knowledge generated are diffused, rather than concentrated in the form of IP rights. It must also be differentiated from some forms of open innovation, which is co-created by multiple creators across firm boundaries, is intended to lead to the acquisition of proprietary rights.

[5] Yochai Benkler, *Law, Innovation and Collaboration in Networked Economy and Society*, 13 ANN. REV. L. & SOC. SCI. (2017); Kevin J. Boudreau & Karim R. Lakhani, *"Open" disclosure of innovations, incentives and follow-on reuse: Theory on processes of cumulative innovation and a field experiment in computational biology*, ELSEVIER, RES. POL'Y, (2015).

[6] Mark A. Lemley & Ziv Shafir, *Who Chooses Open-Source Software*, 78 U. CHI. L. REV. 139 (2011).

[7] Margit Osterloh, Sandra Rota & Bernhard Kuster, Open-Source-Softwareproduktion: Ein neues Innovationsmodell? (2004), http://www.opensourcejahrbuch.de/download/jb2004/chapter_02/II-4-OserlohRotaKuster.pdf; Karim R. Lakhani & Robert G. Wolf, Why Hackers Do What They Do: Understanding

Community members are self-selected based on their abilities relevant to the project; they vet, test and evaluate the quality of the solutions proposed by others.[8]

Innovation in this context is the result of a process, in which knowledge generated upstream is built upon, recombined and cumulated to provide innovation for new products and applications, or for improvements of existing ones.[9] Because OSS communities adhere to an ethos of non-appropriation, all knowledge generated is shared with the community.[10]

The overall strength of the OSS approach lies in the number of contributors and the speed of innovation. Its mechanism is based on collaboration by a potentially vast number of contributors' "eyeballs",[11] with unrestricted access to the entire body of innovation developed upstream relating to the project.[12] This innovation process tends to occur at higher speeds and generate better performance than most proprietary innovation.[13]

B. Open Hardware and its evolution

OSH constitutes a new frontier, in which the open innovation mechanism moves beyond pure information products, into the realm of tangibles[14]. In recent years, technology has made considerable strides by developing the ability to digitally manipulate physical objects. A material object casts an "information shadow."[15] It can therefore be digitally created, represented, modified and transformed with the same relative ease as software goods.[16] When it comes to

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Motivation and Effort in Free/Open Source Software Projects, in PERSPECTIVES ON FREE AND OPEN SOURCE SOFTWARE 1-27 (J. Feller et al. eds., MIT Press 2005).

8 Benkler, *supra* note 5, at 236.

9 Boudreau & Lakhani, *supra* note 5, at 9.

10 Richard Stallman, The GNU Manifesto (1985), https://www.gnu.org/gnu/manifesto.html.

11 ERIC STEVEN RAYMOND, THE CATHEDRAL AND THE BAZAAR: MUSINGS ON LINUX AND OPEN SOURCE BY AN ACCIDENTAL REVOLUTIONARY (1999).

12 Benkler, *supra* note 5, at 9; Dana Beldiman & Fabian Flüchter, *Navigating Patents in an Open Hardware Environment, in* CO-CREATION - RESHAPING BUSINESS AND SOCIETY IN THE ERA OF BOTTOM-UP ECONOMICS 1, 163 (M. Moritz & T. Redlich eds., Springer Verlag, 2018) (unpublished manuscript) (on file with the author).

13 Benkler, *supra* note 5, at 232.

14 Carliss Y. Baldwin & Kim B. Clark, *The Architecture of Participation: Does Code Architecture Mitigate Free Riding in the Open Source Development Model?*, 56 MGMT. SCI. 1116, 1119-21 (2006); Bourdreau & Lakhani, *supra* note 5, at 7-8.

15 Karim Lakhani, Hila Lifshitz-Assaf & Michael Tushman, *Open Innovation and Organizational Boundaries; Task Decomposition, Knowledge Distribution and the Locus of Innovation*, HANDBOOK OF ECONOMIC ORGANIZATION: INTEGRATION ECONOMIC AND ORGANIZATIONAL THEORY 355, 357 (Anna Grandori ed, Edward Elgar Publishing 2013).

16 Lakhani et. al., *supra* note 15, at 357.

transposing it into actual physical three-dimensional objects, practical as well as conceptual complications arise, as will be discussed in further detail below.

Open Hardware is in many ways the hardware equivalent of "open software". It is based on the same creative mechanism as OSS and is predicated on the same motivations and ideology to generate an open and accessible flow of knowledge. The difference lies in the "product". Unlike OSS, where the product is the source code, the OSH product is a physical artifact, electrical, mechanical or otherwise, as well as the knowledge embodied into it.[17] This fact has implications with respect to the structure of the open license agreement, and with respect to contributors' ability to finalize the inventive process by manufacturing and commercializing its output.

The OSH movement began with electronics hardware and initially gained popularity mostly within the amateur community. For reasons of cost and availability of equipment, initially many of its products were one-time hand-manufactured "hacks". The movement has now progressed beyond pure amateur use.[18] However, the number of OSH projects placed on Github and Thingiverse is steadily increasing. A data acquisition campaign for the period 2016-2017 conducted by Bonvoisin and others shows OSH production of machine tools, vehicles, robotics, agriculture, medical prosthetics, diagnostic equipment, musical equipment, power supply, lab equipment, toys and games.[19] Open hardware inventors have formed an umbrella association, the Open Source Hardware Association (OSHWA)[20], which represents the "voice" of the open hardware community, tasked with advocating, educating and uniting stewardship of the open source hardware movement.[21]

Still, the scale of OSH projects remains relatively modest compared to OSS. Several reasons may account for this. First, is the lack of sophistication of available technology. Many OSH projects are implemented in the electronics field, often by manually assembling existing components. The scalability of this technique is limited. However, OSH has seen a considerable boost through the advent of the technology of additive manufacturing or 3D printing.[22]

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[17] John R. Ackermann, *Toward Open Source Hardware*, 34 U. Dayton L. Rev. 183, 216 (2009).

[18] ALICIA GIBB, BUILDING OPEN SOURCE HARDWARE (Addison Wesley ed., 2015.

[19] J. Bonvoisin et al., *What is the "Source" of Open Source Hardware?* J. OPEN HARDWARE., 2017, at 1, 5-6; http://doi.org/10.5334/joh.7

[20] OPEN SOURCE HARDWARE ASSOCIATION, https://www.oshwa.org/ (last visited Nov. 5, 2018).

[21] Gibb, *supra* note 18, at xii.

[22] Stefan Bechtold, 3D printing and the intellectual property system, Research Working Paper No. 28, in ECON. & STAT. SERIES (World Intellectual Property Organization 2015),

This technology is still evolving. In the future, 3D printing is expected to bring cost efficiencies, initially in the form of easy and rapid prototyping, and in the longer perspective, by becoming a principal, large-scale fabrication mode.[23] Second, developing and manufacturing three-dimensional objects is capital-intensive and the path towards funding is not quite clear. Given an environment which does not allow for appropriation of knowledge, on the one hand, and the inchoate state of the technology, on the other, models for capturing the economic value of OSH inventions remain to be developed. The tangible nature of OSH output is likely to complicate matters, as will be explained in detail below. Clearer business models will attract the interest of potential funding sources and scholarly literature can contribute in this regard.

We will now turn to the mechanism that drives open community innovation, which underlies both OSS and OSH. Much of the scholarship in this regard derives from the OSS space and will constitute the primary source of the following discussion.

II. THE OPEN KNOWLEDGE PRODUCTION METHOD – IS OPEN COMMUNITY INNOVATION "FASTER, BETTER, CHEAPER"?

Many have puzzled over the growth and sustainability of OSS. Economic theory is clear that when knowledge is freely shared within a community and not appropriated, it reduces an inventor's ability to contract and, as a consequence, its ability to secure a proper reward for the inventive work. This in turn depresses the incentive to invent.[24]

Development of OSS places this premise in question. The Linux environment, possibly the most successful OSS product, currently runs on more than 82% of the world's smart phones and 92% of the world's supercomputers, while Apache, an open source web-server framework, supports about 67% of the web-servers in the world.[25]

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http://www.wipo.int/edocs/pubdocs/en/wipo_pub_econstat_wp_28.pdf.

[23] Eli Greenbaum, *Three-Dimensional Printing and Open Source Hardware*, 2 N.Y.U. J. INTELL. PROP. & ENT. L. 257, 259, (2013).

[24] Boudreau & Lakhani, *supra* note 5, at 7-8; Jonathan M. Barnett, *The Illusion of the Commons*, 25 BERKELEY TECH. L.J. 1751, 1755 (2010); Amy Kapczynski, *Order without Intellectual Property Law: Open Science in Influenza*, 102 CORNELL L. REV. 1539, 1796 (2017)

[25] Joshua M. Pearce, *Emerging Business Models for Open Source Hardware*, J. OPEN HARDWARE 1, 1 (2017) https://openhardware.metajnl.com/articles/10.5334/joh.4/; *See also* Beldiman & Flüchter, *supra* note 12, at 155-63; ZHUOXUAN LI, ET AL., WHY OPEN SOURCE, EXPLORING THE MOTIVATIONS OF USING AN OPEN MODEL FOR HARDWARE, CONFERENCE PAPER DETC 1, 2 (2017), www.researchgate.net/publication/316884384.

Blockchain, one of the most promising new developments, runs on OSS software.[26] In large companies, open source software has become the *de facto* default standard when it comes to software selection decisions. The open model of knowledge production has come to increasingly supplement and even displace incumbent closed ones.[27] OSS has come to play a more significant role "than was theoretically admissible by economic models of motivation and organization prevailing at the turn of the millennium.

A unique dynamic underlies open source knowledge production: contributors participate in problem-solving communities, motivated by a range of pro-social and personal, but generally non-monetary considerations. [28] These motivations socialize community members to engage in collaborative, rather than competitive interaction and to share knowledge, rather than to appropriate it.[29] The ethos of collaboration, in turn, spawns a pattern of communication among contributors that consists of frequent, freely shared updates, comments and feedback. A rapid cycle of innovative activity - finding, testing, and adopting or discarding solutions - is thus stimulated, in which contributors consume and reuse information on an ongoing basis. This process gives rise to considerable speed in finding solutions and to a great diversity of approaches. [30]

This dynamic seems attributable, primarily to two ingredients: one is the knowledge production mechanism, characterized by early disclosure of upstream information and second, the contributors' motivation.[31] Each will be discussed individually below.

A. Production of Knowledge

1. The anatomy of open inventive activity

Open inventive activity can be conceptualized as a series of problems which are solved by making a large number of interacting decisions. Any given set of parameters of a project will be satisfied by multiple solutions. The initial task is to identify which approach best

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[26] HYPERLEDGER – OPEN SOURCE BLOCKCHAIN FOR BUSINESSES – IBM BLOCKCHAIN, www.ibm.com/blockchain/hyperledger.html (last visited Oct. 23, 2018).

[27] Boudreau & Lakhani, *supra* note 5, at 6; Eric von Hippel, Susumu Ogawa and Jeroen P.J. de Jong, *The Age of the Consumer-Innovator*, MIT SLOANE MAG. 27, 29-30 Fall 2011.

[28] Lakhani & Wolf, *supra* note 7, at 11-12.

[29] Boudreau & Lakhani, *supra* note 5, at 8.

[30] This dynamic is further associated with the absence of a hierarchical structure and full autonomy of the contributors.

[31] Boudreau & Lakhani, *supra* note 5, at 7.

meets the parameters given, in terms of functionality, size, and cost.[32] For instance, if the goal is to construct a sustainable building by capturing a certain quantity of rainwater, the question arises whether rainwater will best be captured through roof structures, window structures or otherwise. Once the approach has been found, say a roof structure has been decided upon, a researcher will look for optimal solutions within that given approach.[33] For instance, it will have to be decided whether a concave or a convex rooftop would be preferable.

Any given decision in this process is made in an environment of uncertainty. To gain certainty, the decision is preceded by a series of trial and error experiments, which provides the researcher with better insight. Initially, these experiments are based on the inventor's own stock of knowledge. Subsequently, they are influenced by a combination of outside factors, heuristics, theoretical understandings, analogies, as well as activities and experiments of others. This process is informed by a steady stream of communications between the researcher and the community in the form of mutual intermediate disclosures: updates by the researcher and observation and feedback by others.[34]

2. Disclosure

It has been posited that when comparing two systems, the collaborative knowledge production model, based on multiple early disclosures, and the conventional single-inventor, "competing with others" model, the former presents advantages over the latter, in that it leads to earlier and more diffused reuse.[35]

In a comprehensive experiment, Boudreau and Lakhani compared the two systems focusing on the interplay between disclosures and reuse of the knowledge disclosed.[36] The first system, referred to as "intermediate disclosure", involves disclosures which occur continuously, as progress is made during the problem-solving process. Knowledge generated upstream is made available for reuse to third parties on an ongoing basis. Its form is not standardized; it may come in varying shapes and quanta of knowledge, including partial and negative results, methods, data, progress etc. This system is commonly practiced within creative collaborative communities. A second system is a conventional single-inventor system, it is roughly

[32] Boudreau & Lakhani, *supra* note 5, at 9.
[33] *Id*. at 9.
[34] *Id*.
[35] *Id*. at 17.
[36] *Id*. at 4.

analogous to inventive activity that might result in a patent grant. Labeled as a "final" disclosure system, its invention is revealed only once the inventive process is completed. It is presented in a standardized format, as an integral and wholly resolved solution. Reuse of the knowledge underlying the invention only occurs after the invention is complete.[37]

3. Intermediate vs. final disclosure

These experiments showed that, when compared to a system based on final disclosure, a system of intermediate disclosure yields more frequent and wider ranging unrestricted disclosures.[38] This fact increases the immediacy and extent of knowledge transfers and promotes more efficient reuse of the knowledge generated. A steady stream of updates allows problem solvers to observe and respond systematically to their own experimentation outcomes and to those of others. This tends to result in differentiated search paths and a greater diversity in approaches to solutions. Once the right approach is found, contributors can converge in a coordinated fashion on the optimal solution, demanding overall less effort and fewer costs, while yielding higher performance

These findings reinforce and validate the openness practices of OSS communities. An open community setting is premised on early and repeated disclosures to many participants. It therefore leads to widespread diffusion of knowledge. The intermediate disclosure system accommodates a greater range and varying quanta of knowledge. For instance, disclosures contain partial and negative results, methods, data, progress etc.[39] This fact promotes (1) a greater diversity in the search paths of individual contributors and (2) greater accuracy in the solution ultimately found, because downstream researchers have access to the entire history (methods, results, etc) and the opportunity to revise and correct.

B. Motivation

Motivation of peer-to-peer community contribution has generated a vast amount of literature.[40] Sociologists now generally

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37 *Id*. at 4-5.

[38] Lakhani & Wolf, *supra* note 7, at 14.

39 *Id*. at 5.

[40] Lakhani & Wolf, *supra* note 7, at 7; Z. Li, *supra* note 25, at 4; Margit Osterloh und Bruno S. Frey, *Managing Motivation: Warum das Thema heute noch brennender ist, Management Wissen*, Markus Sulzberger, Robert J. Zaugg (eds), Springer, 43-49 (2018); Lerner & Jean Tirole, Some *Simple Economics of Open Source*, 50 J. INDUS. ECON. 197, 206 (2002) www.jstor.org/stable/3569837.

accept that rational self-interest does not explain a contributor's willingness to spend numerous hours trying to tackle a community project, with no prospect of monetary gain.[41] A wide range of social motivations, beyond material self-interest alone, [42] play a central role in human behavior.[43]

Based on these recognitions, community contributors are viewed as being motivated by a heterogeneous blend of intrinsic and extrinsic non-monetary motivations.[44] Extrinsic motivation involves doing an activity for some separable consequence and results from feelings such as ego boosts or receiving recognition. It has an important signaling effect; for instance, the open source participation designation of "committer" is a sought-after title in the larger community.[45] Extrinsic motivation is usually externally driven and involves an audience and scales with the size of the audience.[46] Intrinsic motivation, on the other hand, does not contemplate an audience.[47] It is based on individuals' inherent satisfaction of carrying out an activity, their enjoyment or their sense of obligation or community. Some of the dimensions of intrinsic motivation are the desire to be part of a team, the ability to express creativity, experiencing satisfaction and accomplishment, altruism, identification with a particular group, creative discovery, own use, learning-by-doing, a challenge to be overcome and a difficulty resolved.[48] Both types of motivation come into play in open communities.

This motivational structure causes the inventive community to be socialized to collaborative rather than competitive interactions in the course of the innovation process, which, in turn, translate into early and liberal disclosures of knowledge.

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[41] *See generally* Stephen M. Maurer & Suzanne Scrotchmer, Open Source Software: The New Intellectual Property Paradigm NBER Working Paper No. 12148, 12 (2006); Li, *supra* note 25, at 4; Lakhani & Wolf, *supra* note 7, at 5-6.

[42] Maurer & Scrotchmer, *supra* note 41, at 12.

[43] Benkler, supra note 5, at 3.

[44] Lakhani & Wolf, *supra* note 7, at 14; K. Boudreau, N. Lacetera & K. Lakhani *"Incentives and Problem Uncertainty in Innovation Contests: An Empirical Analysis."* 57 MGMT. SCI. 843, 861 (2011).

[45] Lakhani & Wolf, *supra* note 7, at 12; Z. Li, *supra* note 25, at 4; Boudreau et. al., *supra* note 44, at 11.

[46] Z. Li, *supra* note 25, at 4; Lerner & Tirole, *supra* note 40, at 213-14.

[47] Lakhani & Wolf, *supra* note 7, at 4; Z. Li, *supra* note 25, at 4; Boudreau et. al, *supra* note 44, at 861.

[48] Z. Li, *supra* note 25, at 4; Margit Osterloh, Open Source Softwareproduktion: Ein neues Innovationsmodell? (2004), http://www.opensourcejahrbuch.de/download/jb2004/chapter_02/II-4-OserlohRotaKuster.pdf; Maurer & Scrotchmer, *supra* note 41, at 11-12.

C. OSS today- a model for OSH?

Given its primarily non-economic motivational structure, sustainability and scalability of the open source model have been questioned. Some scholars have viewed the early GNU license and movement to free source code, as an outburst of idealism, facilitated largely by the emergence of digitally enabled interactive new ways of communicating and collaborating.[49] It has been suggested that open source ("OS") production is more appropriate for niche applications and may be unable to scale sufficiently to sustain economically viable production.[50]

On the other hand, following its emergence in the 1980s,[51] OS rapidly gained popularity within the software community. Industry and scholarly literature perceived it as a new model of innovation.[52] As pointed out above, Linux currently runs on more than 82% of the world's smart phones and the vast majority of the world's supercomputers.

Today's OS is probably best characterized as multifaceted. Diverse models have emerged, which differ in terms of whether contributors are paid, whether the project is run hierarchically and how it is strategically managed.[53] The most commonly encountered ones, are pure peer community production, evidenced by GNU, CC, Arch Linux and supported by volunteer-developers[54], heterogeneously driven projects, such as Apache and Eclipse, which use mostly paid developers, Linux and Firefox, using some unpaid developers centered around a project, as well as the ones driven and

[49] Stephen M. Maurer, Stepping Stones: Extending the Open Source Idea to Synthetic Biology, SYNBIO AND HUMAN HEALTH, Springer, Dordrecht, (2013), https://doi-org.libproxy.scu.edu/10.1007/978-94-017-9196-0_14.

[50] *See id.*; Jan-Felix Schrape, *Understanding Open-source Software Communities*, CO-CREATION - RESHAPING BUSINESS AND SOCIETY IN THE ERA OF BOTTOM-UP ECONOMICS 72, 78 (M. Moritz & T. Redlich eds., Springer Verlag, 2018) (unpublished manuscript) (on file with the author) (However, is assertion is placed into question by the parallel development of open movement in other areas, such as open science, open academic publishing, creative commons).

[51] The OS movement was born as a reaction to a technology shift, following which companies began treating as proprietary, source code, which had until then been freely accessible. In th1983, Richard Stallman, the founder of OS and the "freeing software" philosophy, developed the GNU open software license, with the aim to contractually ensure propagation of free software and to prevent intellectual property from becoming an instrument of control by owners against users. Richard Stallman, GNU INITIAL ANNOUNCEMENT, https://www.gnu.org/gnu/initial-announcement.html; Brian W. Carver, Share and Share Alike: Understanding and Enforcing Open Source and Free Software Licenses, 20 BERKELEY TECH. L. J. 443, 446 (2005).

[52] Maurer & Scrotchmer, *supra* note 41, at 3.

[53] Schrape, *supra* note 50, at 75-7.

[54] Pearce, *supra* note 25, at 1.

paid for by large corporations, such as Android,[55] where contributors are paid and make their contributions during work hours.[56]

In some of the commercial settings, the social motivation seems to have somewhat eroded, because it can easily be replaced by monetary incentive.[57] It is unclear whether in commercially-based models, the fundamental clash of values between contributors and commercial promoter in terms of hierarchy, autonomy, appropriation of knowledge etc., has been resolved and if so, how.

At the same time, there is little dispute that OSS knowledge production has brought about a change of paradigm, from which many lessons can be learned.[58] OSS has taught that innovation is primarily an emergent property of knowledge flow, brought about by early disclosure, sharing of intellectual resources and collective learning.[59] It has taught that decomposition of tasks into small modules attracts highly qualified contributors,[60] and that, in this manner, a project can be staffed by "the best person to produce a specific module of a project" within a specific time frame.[61] It has further taught greater flexibility in the collaboration between all types of market actors[62] and has opened the door to moving away from rigid organizational structures[63] to create breeding grounds for further innovation in products and infrastructure". [64]

These features will likely be incorporated in OSH, as OSS and OSH share a knowledge production mechanism. It is further reasonable to expect a similar variety of business models will emerge within OSH. We will now turn to the OS license, the legal construct

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[55] Schrape, *supra* note 50, at 75.; *See also* Boudreau & Lakhani, *supra* note 5, at 4-19 (As a result of this convergence, many fail to differentiate between OS, as promoted initially by Richard Stallman and open innovation, a proprietary collaborative creation mechanism, advocated by Henry Chesbrough.)

[56] Lakani & Wolf, *supra* note 5, at 9-10 (have found that 40% of contributors to OSS are paid to participate. Lakhani communities and that 55% of the contributors make their contributions during work hours and receive a salary.)

[57] Maurer, *supra* note 49, at 13-14; Schrape, *supra* note 50, at 76.

[58] Carliss Baldwin & Eric von Hippel, *Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation*, 22 No.6 ORGANIZATION SCIENCE, 1369, 1413-14 (2011), https://doi.org/10.1287/orsc.1100.0618; Yochai Benkler, *Coase's Penguin, or, Linux and The Nature of the Firm*, 112 YALE L. J. 369, 371-72 (2002).

[59] Lemley & Shafir, *supra* note 6, at 141-42.

[60] Benkler, *supra* note 5, at 237; Benkler, *supra* note 58, at 14.

[61] Maurer & Scrotchmer, *supra* note 40, at 23.

[62] Schrape, *supra* note 50, at 78.

[63] Benker, *supra* note 5, at 45.

[64] Recent studies have indicated that with increasing scale and market relevance of an OS project, tends to depart from non-hierarchical, non-structured volunteer work, to a more commercially run structure in which contributors are paid and subject to hierarchical decision-making. Schrape, *supra* note 50, at 74.

that enables the existence of OS as a knowledge production mechanism in the first place.

III. THE LEGAL ARCHITECTURE OF OPEN SOURCE

A. The legal basis of the open license

The open license agreement is a privately ordered, contractual instrument with a dual role. On the one hand, it governs the community and ensures its cohesion and collaborative, non-competing spirit.[65] On the other, it allocates IP rights and permissions relating to the knowledge generated among contracting parties, i.e. to the members of the community.

The OS license is based on the premise that anyone should be able to "see the source … study it, modify it, and share it" and that modifications are to be disclosed under the terms of the original license.[66] Its terms are meant to ensure compliance with the ethos of openness and accessibility by downstream users, so that no portion of a program can be appropriated.[67] It ensures the free flow of knowledge among the potentially large number of recipients which constitutes a project's creative community.

The flow of knowledge within the community is regulated by a set of permissions and prohibitions surrounding the IP rights owned by the contributors, based on the following mechanism: copyright rights arise automatically upon creation, once a work is fixed in a tangible medium of expression.[68] No action is required for these rights to attach. Because copyright is deemed to subsist in any computer program,[69] software developers automatically own copyright rights in any program they create. Copyright owners thus have the right to exclude others from copyright protected acts, including reproduction, modification and distribution.[70] This right to exclude may be contracted away, for instance, by permitting to third parties to access the code, in exchange for the promise that the third party will reciprocate.

Combined, these permissions granted by each developer, form a system of mutual cross-licenses, in which developer-contributors agree to license all their rights in the source code of their product to

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[65] Greenbaum, *supra* note 23, at 259.

[66] *The Four Essential Freedoms of Free Software*, GNU, https://www.gnu.org/philosophy/free-sw.html#f1 (last visited Nov. 3, 2018).

[67] Ackermann, *supra* note 17, at 195.

[68] 17 U.S.C. §101 (2010).

[69] 17 U.S.C. §101 (2010).

[70] 17 U.S.C. §106 (2010).

any other compliant member of the community (licensee). This makes each licensee the recipient of the other parties' (licensors') license grant, and obligates it, in turn, to grant the same rights to others. Two principal obligations are involved: contributors are required to license under the terms governing the original license (1) the source code it develops and (2) the source code to any modifications to existing code.

This structure ensures that both code and modifications are disclosed and passed on to successive downstream licensees. These licensees are entitled to use, extract, reuse, modify and distribute the licensed program to third parties. The owner/licensor also agrees, explicitly or implicitly, not to enforce its rights, as long as the licensee complies with the license terms. In this way, the values of keeping the software free, both in the monetary and the accessibility sense, as well as unrestricted sharing, non-appropriability, attribution, etc. are hard-wired into the agreement. Looping back to the earlier discussion,[71] the open license in effect implements the ingredients of the intermediate disclosure policy outlined by Boudreau and Lakhani: ongoing early disclosures that lead to widespread reuse.[72]

The original open source license limits use of open source code to non-commercial entities, in what is, referred to as a "copyleft" (or share-alike) feature.[73] Contributors are required to license any modifications under the terms of the original license, with the effect that all code subject to a copyleft license, which calls for non-commercial use, must remain non-commercial throughout its downstream use. Because the copyleft license was perceived as too restrictive for certain uses, "permissive" licenses emerged, which allow for downstream commercial use of the licensed material.[74]

In addition to regulating the flow of knowledge in the spirit of openness, open licenses have collateral benefits in that, by their very structure, they increase of participants and diffuse technology. The fact that OSS communities use variants of a pre-existing standardized license terms additionally increases the efficiency of knowledge diffusion. The license offers a convenient and reliable way of transferring knowledge downstream. It will be used by many downstream contributors, because they are familiar with its terms.

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[71] See above discussion early disclosure.

[72] Boudreau & Lakhani, *supra* note 5, at 14.

[73] GNU OPERATING SYSTEM, http://www.gnu.org/licenses/licenses.html (last visited Nov. 3, 2018).

[74] *See e.g.* BSD LICENSE, https://opensource.org/licenses/BSD-2-Clause (last visited Nov. 3, 2018); APACHE LICENSE, https://www.apache.org/licenses/LICENSE-2.0 (last visited Nov. 3, 2018)

This leads to participation of individuals who cannot be identified in advance. The non-proprietary structure of the knowledge flow gives rise to a non-competitive environment, in which developers feel free to share code and an early stage, without fear of appropriation by a third party.[75]

B. Enforceability of open licenses

For many years following the adoption of the open source license, its enforceability was in doubt. Questions were raised, among other things, as to lack of consideration and whether OS licenses are enforceable under contract or under IP law. The dearth of early court decisions on this issue is attributable, in part, to the nature of enforceable rights enforced. OS licenses involve terms that keep IP rights diffused, rather than exclusionary and therefore, in most such instances, no substantial economic value is at stake.[76] Nonetheless, because open license terms constitute the glue that holds together countless software transactions and binds millions of OSS contributors, judicial validation of this license structure is important.

In *Jacobson v. Katzer*,[77] the Federal Circuit removed some of the doubts surrounding OS license enforceability. The court confirmed that IP rights granted as part of an artistic open license are assertible, in holding that the defendant's unauthorized copying of certain textual files, owned by the plaintiff, violated a license condition, rather than a covenant.[78] The legal effect of violating a condition, as opposed to a covenant, is to render the license ineffective, thus leaving the unlicensed use of copyrighted material open to an infringement action.[79] An OS license can therefore form an enforceable contractual relationship. This fact was more recently confirmed in *Artifex Software v. Hancom*, where a California District Court refused to dismiss a plaintiff's contract claim in connection

[75] Maurer & Scrotchmer, *supra* note 41, at 14; Ackermann, *supra*, note 17, at 195.

[76] OSS licenses are seldom asserted in courts. One reason for this is that enforcement would be in the direction of "openness", i.e. it would enforce terms meant to keep knowledge and IP rights diffused among the members of the community, rather than concentrated in one or a small number of owners, as a conventional IP license would. Therefore, in most instances, no substantial economic value is at stake in open licenses and there is little incentive to sue (although this must be qualified in light of statutory copyright damages which may be imposed regardless of the amount in dispute. 17 U.S.C. § 504(c)).

[77] Jacobsen v. Katzer, 535 F.3d 1373, 1383 (Fed. Cir. 2008).

[78] *Id.*

[79] The scope of this holding remains in dispute. Some believe its significance may be limited contract construction, which would vary from state to state. Hersh R. Reddy, *Jacobsen v. Katzer: The Federal Circuit Weighs in on the Enforceability of Free and Open Source Software Licenses,* 24 BERKELEY TECH. L. J. 299, 310 (2009).

with a GNU license.[80] Similar decisions have been issued in other jurisdictions.[81]

Certain tension points are expected to continue causing disputes in OSS licenses. These include the failure to attribute, as well as unauthorized incorporation in proprietary products of the material licensed under a copyleft license, such as GPL. A possible outcome would be that such acts constitute a breach of the license agreement and would entitle the creator to bring a claim for copyright infringement. Breach of a contractual clause might void the effect of the license, resulting in a finding of infringement against the breaching party. Remedies could consist of damages or an injunction, requiring the infringer to cease use of the licensed material.

The discussion, so far, has concentrated on general principles of open licenses, illustrated primarily by OSS licenses. We will now focus on the specifics of OSH licenses and how they differ from OSS licenses.

C. The Open Hardware license

OSH licenses have been adapted from the OSS license to fit the needs of hardware design. They are built on the same structural and ideological principles and have largely the same features as OSS licenses. Some of the better-known licenses are the TAPR Open Hardware License[82] and the CERN Open Hardware license.[83]

The fundamental difference, compared to OSS, is the relation to copyright. The OSS license works well, because copyright arises automatically upon creation. It constitutes a license obligation trigger or "hook" with respect to any copyrightable materials created within the community. Source code, the product of OSS innovation, is presumptively copyrightable and gives its the owner the power to contract.

This mechanism does not necessarily work for the OSH license. The output of the OSH process consists of (1) documentation, instructing the user how to build the hardware product and (2) the hardware product itself. The documentation follows the principles of the OSS license, because most of its components, such as text,

[80] Artifex Software, Inc. v. Hancom, Inc., No. 16-cv-06982-JSC, 2017 U.S. Dist. LEXIS 62815, at *18 (N.D. Cal. April 25, 2017 and September 12, 2017) (The matter was settled out of court in December 2017.)

[81] *E.g.* Welte v. Sitecom Deutschland GmbH, case nr. 21 O 6123/04, Munich District Court (May 19, 2005).

[82] THE TAPR OPEN HARDWARE LICENSE, www.tapr.org/ohl.html (last visited Nov. 3, 2018).

[83] CERN OHL VERSION 1.2, www.ohwr.org/documents/294 (last visited Nov. 3, 2018).

drawings and code, are presumptively copyrightable. They can operate as a license hook much in the same manner as source code does and trigger copyright enforcement. However, when it comes to the physical hardware product, there are serious doubts as to whether it can be subject to copyright, and therefore as to its reliability as a trigger.

For this reason, the OSH license grants rights to the two outputs of the innovative process (1) the Documentation and (2) the Product, the physical hardware output created based on the Documentation.[84] The following will give an overview over each of these provisions in turn.

1. Rights in the "Documentation" as trigger of license obligations

The primary trigger of license obligations under the OSH license is the Documentation. It contains all the information necessary to construct the physical output and may include schematic diagrams, designs, circuit or circuit board layouts, mechanical drawings, flow charts and descriptive text, and other explanatory material.[85]

a. Copyright

These items may fall into protected categories of "works" under copyright laws. It can be assumed that text and code are protectable as "literary works" in the US, as well as in most members of the Berne Convention;[86] schematics of circuits, engineering and technical drawings, as well as CAD and STS files may qualify for copyright protection; in the US as "pictorial, graphic and sculptural" works;[87] a video would be protected as audio-visual work.[88] The various components of the Documentation would be entitled to protection, as long as they display a modicum of creativity.[89] Once these requirements are met, they are presumptively sufficient to trigger copyright rights to the documentation for purposes of the OSH license.[90] A contributor/licensor would thus acquire exclusive rights

[84] Ackermann, *supra* note 17, at 192.
[85] CERN OPEN HARDWARE LICENSE, https://www.ohwr.org/projects/cernohl/documents (last visited Nov. 3, 2018).
[86] Oracle America v. Google, Inc., 750 F.3d 1339, 1354 (Fed. Cir. 2014).
[87] Bechtold, *supra* note 22, at 14.
[88] It should be noted that these are assumptions as to protectability, which have not been tested in court
[89] Feist Publications v Rural Telephone Service Co., 499 U.S. 340, 341 (1991).
[90] Victor Stanley, Inc. v. Creative Pipe, Inc., No. MJG-06-2662, 2011 U.S. Dist. LEXIS 112846 (D. Md. Sept. 30, 2011).

of reproduction, modification and distribution of the Documentation, which can be contracted.

A wrinkle appears when the Documentation is used to make the hardware product, but the user does not actually engage in one of the acts prohibited by copyright law. For instance, if a user were to merely "use" the documentation to construct a product, but not engage in an act prohibited by copyright, such as reproduction, modification or distribution, copyright law would not be infringed.[91] A user who makes the product based on reading the documentation, would therefore escape liability because (a) no act infringing copyright in the documentation can be shown, and (b) there generally is no copyright in a three dimensional utilitarian product. This constitutes a gap in the OSH license's enforceability (unless the contributor had separately secured patent protection).

While the manufacture of a physical object by traditional means probably does not infringe copyright, it has been suggested that manufacture by way of a 3D printing process does.[92] The argument is based on the use of CAD and STL design files during the 3D printing process. To 3D print a design file, a user would have to copy the files into the memory of the 3D printer. Throughout the printing process these files are transformed into a series of print-ready two-dimensional slices. A user thus engages in two acts prohibited by copyright, reproduction and modification (making a derivative work). This would trigger the copyright protection required for the license to be enforceable.[93]

b. Patent

Some portion of the Documentation, such as circuits or circuit board layouts may be patentable, if they fulfill the requirements of being new, useful and non-obvious[94] and do not consist of merely abstract ideas.[95] Patents are not common in the open hardware environment, possibly because procuring patent protection is relatively time consuming and costly, but also because appropriating knowledge in the form of exclusive IP rights is contrary to the ethos of open hardware.[96] Still, in some cases, patents may be the only

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[91] Gusler v. Fischer, 580 F. Supp. 2d 309, 315 (S.D.N.Y. 2008).

[92] Greenbaum, *supra* note 23, at 275-76.

[93] *Id*. at 276-77.

[94] 35 USC §§101, 103.

[95] Alice Corp. Pty. v. CLS Bank. Int'l, 134 S.Ct. 2347, 2354 (2014).

[96] Jason Schultz & Jennifer Urban, *Protecting Open Innovation: The Defensive Patent License as a New Approach to Patent Threats, Transaction Costs, and Tactical Disarmament*, 26 Harv. J. L. & Tech. 1, 10 et. seq. (2012).

contractable IP right by which the OSH can trigger license obligations with respect to a particular product. Unlike copyright, patent rights do not arise upon creation, and consequently, cannot automatically trigger license obligations. Nonetheless, if procured, they can serve as trigger and, to this end, some of the OSH licenses have been modified to accommodate patent rights.[97] Once obtained, the patent rights are licensed under the open license and subject to the same license obligations as exclusive rights under copyright law. The patent owner grants to all community members the right to practice the invention, or, alternatively, a personal immunity from suit relating to the patent(s).[98] Furthermore, licensees must license any improvements under the terms of the original license.[99] In other words, the OSH licensed patent does not primarily play an exclusionary role, but rather an inclusive one, by creating a permissive zone around the documentation and the physical product, in which users are free from infringement liability to the patentee, but not from infringement claims brought by third parties.

Under certain circumstances, however, the documentation may operate as a "defensive patent publication" and even insulate from infringement actions by third parties.[100] This is because a sufficiently widespread publication of an invention may destroy its novelty and render the invention unpatentable to others, by placing it into the public domain.[101] This eliminates the risk of possible future infringement actions. In some industries it is common practice to publish "defensively", in order to maintain patent-free space.[102]

An effective defensive publication must function as an "enabling" description, in other words, it must describe the invention in sufficient detail to allow others skilled in the respective art, to practice it and make the product. To be effective, a defensive publication must further include a description of the idea of the

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[97] TAPR Open Hardware License v1.0, TAPR (May 25 2007), www.tapr.org/TAPR_Open_Hardware_License_v1.0.txt; CERN Open Hardware License v.1.1, CERN (Jul. 13, 2011), https://ohwr-production.s3-eu-west-1.amazonaws.com/uploads/attachment/file/662/CERNOHLv1_1.pdf?X-Amz-Expires=600&X-Amz-Date=20181024T191705Z&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAJDWHW5JNHWMBZXXQ/20181024/eu-west-1/s3/aws4_request&X-Amz-SignedHeaders=host&X-Amz-Signature=262a152882657248aa40c06f7801245c0af47439c7db824c081d65c044e76135.

[98] Ackerman, *supra* note 17, at 194.

[99] *See, e.g.,* TAPR license, *supra* note 97, section 2.2.

[100] Beldiman & Flüchter, *supra* note 12, at 157-63.

[101] 35 U.S.C. §102(b) (2011).

[102] DEFENSE PUBLICATIONS, www.defensivepublications.org (last visited Nov. 3, 2018).

invention, its function, the flow of data, as well as applicable drawings or figures.[103]

OSH Documentation can operate much like a defensive publication: it is designed to record in detail every iteration, trial and error, partial solutions and final solution in the development of the product. Its purpose is to instruct downstream users on how to produce the invention, with sufficient specificity to allow a person skilled in the field to make the product. If published in a manner accessible by the public, OSH documentation may well meet the requirements of a defensive publication with respect to the product or project at issue. In this role, use of the Documentation achieves the open hardware's goal by a different path: it diffuses knowledge, not by binding licensees to openness, but by placing the invention in the public domain.

Finally, patent protection may serve its traditional exclusionary function and prevent non-licensees from practicing the invention. Even if a patent owner-licensor has issued non-exclusive licenses to several licensees, it would typically still be entitled to prevent an unauthorized user of the invention from practicing it. Depending on the circumstances, sufficient exclusionary value may be left in the patent in order to allow its owner to extract economic value from it. This avenue is, of course, foreclosed in the event the Documentation has been used as a defensive publication.

2. Rights in the "Product" as trigger of license obligations

The OSH license also grants rights to the "Product". Product in this context is the physical output of the OSH innovation process, in the form of an electronic, a 3d printed or any other physical object, that is generated through the OSH process based on the Documentation.[104] Products are best protected by patent. Copyright applies only qualifiedly.

a. Copyright

Copyright protection for physical three-dimensional objects is generally limited to products which are artistic in nature. Utilitarian products are not copyright protectable for the following reasons.

For purposes of copyright protection, three-dimensional works are evaluated under the standards of the "pictorial, graphic,

[103] Beldiman & Flüchter, *supra* note 12, at 158.

[104] See *supra* Section 4.3.1.

sculptural" works doctrine.[105] Under this doctrine, a "useful article", i.e. an article with an intrinsic utilitarian function is not copyright protectable. In cases in which a product displays both utilitarian and artistic features, it must be determined whether the article's aesthetic features can be identified and can exist separately from its utilitarian aspects.[106] To that end, a court would look first, whether the artistic features can be perceived as a two- or three-dimensional work of art separate from the useful article, and second, whether, if it were imagined separately from the useful article into which it is incorporated, it would qualify as a protectable pictorial, graphic, or sculptural work—either on its own or fixed in some other tangible medium of expression.[107] This standard is difficult to meet and most utilitarian products would probably fail. However, OSH developed artistic objects, such as sculptures manufactured by means of the 3D printing process, would stand a better chance of meeting the "useful article" test.[108]

Absence of copyright protection for utilitarian OSH products means that an inventor cannot bind downstream licensees by a right that arises automatically. The OSH license may therefore not be enforceable when it comes to utilitarian Products, to the extent it relies solely on copyright. This fact does not necessarily have serious ramifications: as long as the OSH license also conveys rights in copyrightable, the can, as described in detail above, act as a license trigger. In the alternative, patent protection would ensure that the OSH license remains enforceable as far as the Product grant is concerned.

b. Patent

Patent law is the proper IP instrument to protect utilitarian OSH Products. How it applies to physical products, is largely the same as described under Documentation above.[109]

3. Know-How and latent knowledge

Know-how is not expressly mentioned in the license agreement; however, it is omnipresent in the process of community innovation and deserves separate discussion. As used for present purposes, it is the combined, cumulative knowledge on how to develop and

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[105] 17 U.S.C. §101.
[106] Star Athletica, L.L.C. v. Varsity Brands, Inc., 137 S. Ct. 1002, 1010 (2017).
[107] *Id*. at 1011.
[108] 17 U.S.C. §101; *See generally* Star Athelica, L.L.C., 137 S.Ct. at 1008-10.
[109] *See supra* section 4.3.1.b Patent.

manufacture a physical product, generated in the course of a given OSH invention, regardless of any IP rights which may apply.

Most of this know-how refers to the invention process of trial and error, partial results, tentative solutions, final solutions, etc. and is captured by the Documentation. That part is available for immediate reuse by community members. Separately, in the context of community innovation, most often an additional type of know-how exists, which will be referred to as latent know-how. [110] Latent know-how is not contained in the Documentation. This is so, because the Documentation primarily records the result of relatively linear thinking in pursuit of a solution to a given problem. Information that appears to be of lesser relevance to the immediate innovation outcome, such as general knowledge, alternative paths that have been discarded, collateral observations, etc. may not be reflected in the Documentation. Latent know-how is akin to "sticky" knowledge, described by Eric von Hippel,[111] in that its transfer out of the community would be difficult or even impossible and come at a high cost. However, latent knowledge exists within the community and is low hanging fruit, easily accessible if the problem is posed slightly differently, say, in the course of improving the original solution.[112] As will be discussed below, whether or not it can be tapped into successfully is a function of the relationship between the inventive community and the implementer.[113]

This concludes the discussion on the flow of knowledge associated with the OSH inventive process and its fixation into contractual obligations that govern the inventive community. Next, we will examine the ability to capture economic value in the context of an OSH invention, in which knowledge is widely diffused.

IV. CAPTURING VALUE FROM CONSTRUCTING A TANGIBLE PRODUCT

It is commonly accepted that control over its IP rights is required for capturing economic value from an invention. The ability to

[110] Formalized knowledge is knowledge that is captured in the Documentation or other means in which it is easily transmissible to third parties. Latent knowledge is knowledge which has not been formally captured, but it is knowledge that was a part of the inventor's mental process during the inventive process, e.g. trial and error, alternative search paths, discarded experiments, etc.

[111] Eric von Hippel, *"Sticky Information" and the Locus of Problem Solving: Implications for Innovation*, MGMT. SCI. 429, 429 (Apr. 1994) https://doi.org/10.1287/mnsc.40.4.429.

[112] This latent know-how may be suggested by or hinted at in the Documentation, but it may be a completely new approach triggered by the altered question.

[113] *See infra* section 5.4.

capture value operates to attract investment.[114] Both OSS and OSH present a challenge in this regard, as knowledge is diffused and exclusively appropriable IP rights are unavailable. Compared to OSS, OSH however, faces higher hurdles, because greater financial resources are required to produce and commercialize physical products.

A. Atoms vs. bits - the tangible nature of OSH

The core difference between a OSS and a OSH product is that the OSS product is digital, i.e. consists of bits, while the OSH product is tangible and consists of atoms. [115] The processes required to ready software for final use are all digital, because software is self-executing, in that the necessary instructions are incorporated in the program itself and carried out automatically. On the other hand, a tangible OSH product requires multiple operations such as testing, prototyping, marketing, permitting, manufacturing, storage, shipping and distribution before getting to the end-user. In addition, component parts and raw material must be purchased and physical manufacturing space must be secured.[116] All these tasks involved are labor- and capital-intensive. How can an individual inventor or an OSH inventive community fund all these operations?

B. Inventor commercialization

The most approachable way to meet the financial obligations of production, and at the same time to preserve the open community ethos, is for an OSH inventor is to self-finance, rely on donations or grants, or find a business model which, at a minimum, covers costs. The simplest model is for the inventor to self-fund the manufacture and sale of product in the market. A leading example is Aleph Objects,[117] which sells the OSS and OSH Lulzbot 3D printer, used to make scientific tools such as tube racks, centrifuges and microscope accessories.[118] An alternative approach is to license the technology

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[114] Investment is generally based on the expectation of capturing economic value from the invention. Economic value can best be captured with the right to control the invention in the form of IP constitutes the necessary “currency” to attract investment.

[115] Additional factors differentiate OSS from OSH, including (1) the tools available. Easily useable CAD tools are still being developed. For instance, on Github sharing and distributing the work and debugging is easier than for OSS than OSH. (2) the self-executing feature of software gives rise to a sense of immediacy of the “reward” for contributor. GITHUB, https://github.com (last visited Nov. 3, 2018).

[116] Bonvoisin, *supra* note 19, at 3.

[117] ALEPH OBJECTS, www.alephobjects.com (last visited Nov. 3, 2018).

[118] Pearce, *supra* note 25, at 5.

under an open source license, while securing trademark protection for any products sold, entitling the inventor to royalties for third party sales. This model is being used successfully by the Arduino OSH ecosystem.[119] In addition to its platform, which is made available on an open source basis, Arduino offers consulting services relating to its technologies. Funding can also be secured from non-profit organizations or through crowdsourcing. For instance, with the help of funding from a foundation, Open Source Ecology (OSE) is developing open source blueprints of a set of "the 50 most important machines that it takes for modern life to exist – everything from a tractor, to an oven, to a circuit maker."[120] The blueprints are published on an open platform and freely accessible to any interested user, OSE also runs paid-for workshops.[121]

In the instances cited above, the IP rights are diffused in that the designs underlying the product are publicly available. The inventors' strategy in these instances is to out-innovate possible competition, by relying on the ongoing stream of low cost research and development that flows from the innovative community. In conjunction with their communities, these inventors have developed a high degree of latent expertise and knowledge, which allows them to readily come up with solutions for improvements, further development and new applications. Reliance on the same inventive community on an ongoing basis brings with it the competitive advantages of easily tapping into latent knowledge and of conveying a certain guarantee of quality of the product.[122] These benefits are unavailable to outsiders, even though they may have access to the designs.[123]

Absent relatively substantial investment, likely from a for-profit actor, the inventor commercialization model has limitations in that it is hard to scale. At this point, pure OSH companies operate mostly as niche providers.[124]

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[119] ARDUINO, www.arduino.cc (last visited Nov. 3, 2018).

[120] OPEN SOURCE ECOLOGY, https://www.opensourceecology.org/ (last visited Nov. 3, 2018).

[121] OPEN SOURCE ECOLOGY, http://opensourceecology.org/wiki/Why_OSE_Doesn%27t_Support_the_Use_of_Creative_Commons_Non-Commercial_Licenses (last visited Nov. 3, 2018).

[122] *E.g.* ARDUINO, www.arduino.cc (last visited Nov. 3, 2018).

[123] Lars Zimmermann, *The Open Source Hardware and Open Design Business Models Matrix*, BUILDING OPEN SOURCE HARDWARE, (Alicia Gibb, ed., 2015).

[124] An exception to this is Red Hat, which operates based on a model in which paid-for services are provided on top of the original open source program. RED HAT, www.redhat.com (last visited Nov. 3, 2018).

C. IP prerequisites for commercially based exploitation

The need to scale the operations surrounding an OSS/OSH product raises the question of securing investment, and, in turn, of the economic incentive to invest into an OSH invention. A commercially-oriented firm would expect to receive a quantum of IP rights that give the firm exclusivity or at least a sufficient degree of control, to place it in favorable position in the market. Such rights would take the form of a license "package" that grant the licensee exclusive rights, or at least control over the relevant IP rights, for the maximum possible duration. In addition, an investor-licensee would receive safeguards of enforceability, such a clear description of the contracting parties, a listing of the rights transferred, comprehensive definition of the product licensed and of the rights granted, e.g. control of rights to manufacture, use, sell, replicate, etc. the physical product, including any software, know-how, drawings, documentation, as well as exclusivity in specified markets, as well as various warranties and indemnities, termination provisions, etc.

This quantum and structure of rights is not available in a community innovation setting because the logic underlying community innovation value creation by early and frequent disclosures. By way of the rights anchored in the OSH license, OSH promotes diffusion, rather than concentration of knowledge and allows value to be captured by the community, rather by a single economic actor.[125] This structure not only allows free use by the community but encourages third-party users of the technology to enter the market.[126]

In short, a community invention setting does not generate appropriable IP rights which could place an investor in a favorable competitive position.[127] Rational economic actors would therefore have little incentive to invest in the commercial exploitation of a pure open source invention.[128]

D. Capturing value in the absence of IP rights

Because, as described above, pure community inventions tend not to attract investment from commercially oriented firms, various hybrid models of exploitation have emerged. They range from pure

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[125] Henry Chesbrough & Melissa Appleyard, *Open Innovation and Strategy*, 50 CAL. MGMT. REV. 57, 62 (Fall 2007).

[126] *Id*.

[127] Benkler, *supra* note 5, at 234; Maurer & Scrotchmer, *supra* note 41, at 7; Pearce, *supra* note 25, at 1; Chesbrough & Appleyard, *supra* note 125, at 58; Greenbaum, *supra* note 21, at 261.

[128] Boudreau & Lakhani, *supra* note 5, at 16-17.

peer community projects, driven by volunteers, to corporate-led projects and often are combinations of the two.[129] These models bundle OSH inventions with IP-based ones:[130] one may function as the primary profit center, while the other may serve as add-on or complementary products. [131] For instance, if a proprietary cell phone uses an open source application or operating system, the value of the proprietary phone would be enhanced by the free nature of the open technology. [132] In effect then, even though the community invention's IP rights are diffused, the invention can add to the overall ability to make a profit.[133]

Hybrid models combine two heterogeneous systems: one property-based, the other is community-based. These systems diverge in ethos and values. As will be explained below, tensions may arise from this. careful management of the boundary between systems is mandated.[134]

E. Ongoing collaboration with the community as primary source of innovation – clash of values

In a hybrid business model, that combines community innovation with commercial implementation, the source of innovation generally continues to be the community. Activities such as testing, prototyping, manufacturing, but importantly, also product improvements and further development, typically draw on the community innovation, and require an ongoing exchange of information between implementer and community.[135]

However, the values of the two groups are misaligned.[136] A commercial firm seeks to appropriate formal IP rights in order to extract economic value from the invention. Open communities have typically opted out of formal IP and adhere to a regime of sharing and open disclosure of knowledge. This ideological misalignment may give rise to tension in different ways.

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[129] Schrape, *supra* note 50, at 77. Hybrid projects, such as Linux and Firefox, are centered around a project led by a project manager, using some volunteers but mostly paid developers. *See also* Benkler, *supra* note 5, at 234; Lakhani, *supra* note 15, at 356.

[130] David J. Teece, *Business Models, Business Strategy and Innovation*, 43 ELSEVIER LONG RANGE PLANNING 172 (2010).

[131] Chesbrough & Appleyard, *supra* note 115, at 60-61.

[132] *Id*.

[133] *Id*.

[134] Maurer & Scrotchmer, *supra* note 41, at 22.

[135] Benkler, *supra* note 5, at 232; Boudreau & Lakhani, *supra* note 5, at 17.

[136] Katherine Strandburg, *Intellectual Property at the Boundary*, N.Y.U. PUB. L. & LEGAL THEORY WORKING PAPERS 1, 33 (2013).

One source of tension is the difference in organizational structures. An open community usually consists of volunteers and functions in a non-hierarchical, non-structured manner. Community contributors act as autonomous, spontaneous problem-solvers, at a time and in a space determined by them. A hybrid model, on the other hand, tends to push for a commercially run structure, subject to hierarchical decision-making. It favors paid contributors.[137] With increasing scale and market relevance of a project, the pressure to impose more orchestrated goals and specific deadlines and operate in a strictly commercial manner also increases.[138]

Further tension flows from differing expectations regarding the transfer of knowledge. A commercial firm generally expects an invention to be handed over in a complete package, which contains substantially all the information required for productization, as would be the case with a patent. However, innovation is an iterative process, characterized by uncertainty, in an environment of successive trial and error experiments. In an open community setting, innovation is the result of ongoing communications among members of the community, queries, updates, receipt of observations and feedback, solutions found, discarded, modified, readopted and improved.[139] The innovation is therefore contained in sequential, iterative and often messy disclosures. Furthermore, certain latent or "sticky" knowledge remains within the community. [140] Its transfer away from the community comes at the cost of maintaining a smooth collaborative relationship[141] requires sensitive management of the community relationship.

Finally, allocation of benefits of the creative output between community and implementer may be a source of discontent. If community members' perceive that the commercial operator receives disparate profits, their motivation may be undermined.[142]

In short, the ideological misalignment between the two systems risks destabilizing their collaboration.[143] If community members drop out for lack of motivation or because they question the integrity and values of the community, its internal governance regime is threatened.

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[137] Schrape, *supra* note 50, at 75-7.
[138] *Id*.
[139] Boudreau & Lakhani, *supra* note 5, at 10.
[140] *See supra* section 4.3.3.
[141] von Hippel, *supra* note 111, at 34. The greater the novelty of the invention, the larger the measure of "stickiness".
[142] Strandburg, *supra*, note 136, at 22.
[143] *Id*.

A real possibility exists that the community may collapse,[144] as contributors have alternate ways of spending their time and talent. For the implementer, on the other hand, severing the interaction with the community would come at a high cost, in that it would deprive the commercial actor of its source of innovation.[145] All of this, presents a strategic challenge for both groups. Mutual finesse is required in order not to alienate the other group.[146]

CONCLUSION

The success of collaborative, community open innovation has been evidenced primarily in the context of open source software (OSS), i.e. the realm of intangible, digital products (bits). This paper asks whether the success of OSS can be replicated in an environment involving three-dimensional tangible products (atoms), or open hardware (OSH). To this end, we have examined OSS and OSH from several perspectives.

The first aspect considered was the open community innovation mechanism, common to both OSS and OSH. Both follow an intermediate disclosure system, which involves early and repeated disclosures of the knowledge that underlies the innovation. This fact leads to its wide diffusion and frequent downstream reuse giving rise to an overall enhanced innovation power. However, we also noted that widespread diffusion of the knowledge underlying the innovation is in tension with the appropriability of IP and the need for investment.

The second aspect considered, was the structure of the open license. Certain differences exist between OSS and OSH licenses, necessitated by the tangible nature of the hardware product. The OSS license is based on the fact that copyright arises automatically upon creation. Every software developer thus owns a contractable IP right. Combined these rights underlie the OSS license. OSH products, which are tangible, are not necessarily subject to copyright law, a fact which raises a question as to the enforceability of the OSH structure. However, it is likely that this problem has been addressed by the fact that the OSH grants a license in the "Documentation", most of whose components are likely subject to copyright.

Third, we looked at what steps are necessary for each final product to reach its end-user. Software is self-executing, in that all instructions for implementation are incorporated into the product and

[144] Chesbrough & Appleyard, *supra* note 125, at 62.
[145] Strandburg, *supra* note 136., at 22.
[146] *Id.*; Chesbrough & Appleyard, *supra* note 125, at 71.

executed digitally. Consequently, its implementation entails relatively low costs. Hardware, on the other hand, requires labor and cost-intensive operations associated with manufacture, distribution, etc., which require investment. Commercial firms are generally motivated to invest by the availability of appropriable IP rights. No such rights are available under the open source license because its effect is to diffuse, rather than concentrate rights for purposes of appropriation. This suggests that the tangible nature of a product makes it more difficult to realize the full social value of a community invention. Does this fact however negate the ability to implement open larger scale community projects in the hardware space altogether? In the OSS field certain hybrid business models have evolved, which make successful commercial exploitation at a larger scale possible. These models combine complementary IP-based products with community innovation. In this manner, the non-appropriability of the community innovation tends not to detract from the ability to monetize the combined product. A scalable hybrid model in the hardware context can therefore not be ruled out.

Finally, the inventive community is the continuing source of innovation and value. This fact entails two aspects. A large quantum of latent or "sticky" knowledge resides in the community, which can be tapped by the implementer for purposes of improvements and further innovation. In order to take advantage of this resource, a sustainable relationship with the community is necessary. This relationship may be difficult given the clash of ideology between open community values and the goals of commercially-oriented implementers. Managerial finesse and people skills are required to manage this relationship.

To sum up, this article concludes that the innovative power of OSS (bits) can be replicated in an environment involving three-dimensional tangible products (atoms). Even though OSH products face considerably greater hurdles to overcome compared to OSS products, in a hybrid business community – commercial business model, economic value can be captured from OSH inventions.