

Horizontal innovation networks - by and for users

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ABSTRACT

Innovation development, production, distribution and consumption networks can be built up horizontally – with actors consisting only of innovation users (more precisely, “user/self-manufacturers”). Some open source software projects are examples of such networks, and examples can be found in the case of physical products as well. In this paper we discuss three conditions under which user innovation networks can function entirely independently of manufacturers. We then explore related empirical evidence and conclude that conditions favorable to horizontal user innovation networks are often present in the economy.

Keywords:

horizontal innovation networks, user innovation, information revealing.

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1.0 Introduction

Innovation development, production, distribution and consumption networks that are distributed horizontally across many software users exist in the field of “free” and “open source” software projects,¹ and in many other fields as well. These horizontal user innovation networks have a great advantage over the manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years: they enable each using entity, whether an individual or a corporation, to develop exactly what it wants rather than being restricted to available marketplace choices or relying on a specific manufacturer to act as its (often very imperfect) agent. Moreover, individual users do not have to develop everything they need on their own: they can benefit from innovations developed by others and freely shared within and beyond the user network.

In the functional sources of innovation lexicon, economic actors are defined in terms of the way in which they expect to derive benefit from a given innovation. Thus, “users” are firms or individual consumers that expect to benefit from *using* a product or a

¹ “Free” or “opensource” software means that a user possessing a copy has the legal right to use it, to study the software’s source code, to modify the software, and to distribute modified or unmodified versions to others. A software author uses his or her own copyright to guarantee these rights to all users by affixing any of a number of standard licensing notices, such as “Copyleft,” to the code. Well-known examples of free or open source software are the GNU/Linux computer operating system, Perl programming language, and Internet e-mail engine SendMail (Raymond 1999).

The practice of granting extensive rights to users via licensing began with the free software movement started by Richard Stallman in the early 1980s. Stallman founded the Free Software Foundation (FSF) to counter the trend towards proprietary development of software packages and release of software without accompanying source code. The open source movement was started in 1998 by a number of prominent computer “hackers” such as Bruce Perens and Eric Raymond. This group had some political differences with the free software movement, but agreed in general with the licensing practices it had pioneered, and also had new ideas as to how to spread these practices more broadly.

Many thousands of free and open source software projects exist today and the number is growing rapidly. A repository of open source projects, Sourceforge.net, lists in excess of 40,000 projects and more than 400,000 registered users. Implementing new projects is becoming progressively easier as effective project design becomes better understood and prepackaged infrastructural support for such projects, such as is provided by SourceForge, becomes available on the Web.

service. In contrast, “manufacturers” expect to benefit from *selling* a product or a service. Innovation user and innovation manufacturer are the two general functional relationships between innovator and innovation. Users are unique in that they alone benefit *directly* from innovations. All others (here lumped under the term “manufacturers”) must sell innovation-related products or services to users, indirectly or directly, in order to profit from innovations. Thus, in order to profit, inventors must sell or license knowledge related to innovations, and manufacturers must sell products or services incorporating innovations. Similarly, suppliers of innovation-related materials or services must sell the materials or services in order to profit from the innovations. (For example, an oil supplier benefits from the development of an improved oil lamp via increased sales of oil.)

By user “network” we mean user nodes interconnected by information transfer links which may involve face-to-face, electronic or any other form of communication. User networks can exist within the boundaries of a membership group but need not. User innovation networks also may, but need not, incorporate the qualities of user “communities” for participants, where these are defined as “...networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity.” (Wellman 2002 p. 4).

It is our contention that complete fully-functional innovation networks can be built up horizontally – with actors consisting only of innovation users (more precisely, “user/self-manufacturers”). Users participating in the network design and build innovative products for their own use – and also freely reveal their design information to others. Those others then replicate and improve the innovation that has been revealed and freely reveal their improvements in turn – or they may simply replicate the product design that has been revealed and adopt it for their own, in-house use.

Non-users also may contribute to what we are calling user innovation networks. For example, in the case of open source software innovation networks, manufacturers of complementary goods and purveyors of complementary services can be motivated to contribute, if and as the innovations they freely reveal enhance profits from what they sell (E.g., manufacturers of proprietary computer hardware can have an incentive to create and contribute novel open source software that will improve the link between a popular open source software program and their proprietary hardware.) (Harhoff et al 2003). Also, computer programmers that have no use for the software they are developing may

contribute, driven by enjoyment of the work itself, reputation effects, etc. (Lerner and Tirole, 2002). It is also the case that users may apply pre-existing products commercially produced by manufacturers and/or apply pre-existing commercial processes to create or reproduce user innovations. It is only our contention that innovation-specific investments and activities by such non-users are not essential, and that horizontal, distributed innovation networks containing only user participants can be fully functional.

Specifically, we propose that user-only innovation development, production, distribution and consumption networks can flourish when (1) at least some users have sufficient incentive to innovate, (2) at least some users have an incentive to voluntarily reveal information sufficient to enable others to reproduce their innovations, and (3) user-self production can compete with commercial production and distribution. When only the first two conditions hold, we propose that a pattern of user innovation and trial will occur within user networks, followed by commercial manufacture and distribution of innovations that prove to be of general interest. In this paper we will explore these matters and will attempt to show that conditions favorable to user innovation networks often do exist in the real world economy.

1.1 Examples of user innovation networks

User innovation networks have existed long before and extend far beyond open source software. Such communities can be found developing physical products as well. Consider and compare the following two examples of early stage user innovation networks, the first in software, the second in sports. Note especially their “user-only” nature with respect to both innovation development, the diffusion of innovation-related information, and innovation self-manufacture.

Apache Server Software

Apache open source software is used on web server computers that host web pages and provide content requested by Internet browsers. Such computers are the backbone of the Internet-based World Wide Web infrastructure.

The server software that evolved into Apache was developed by University of Illinois undergraduate Rob McCool for, and while working at, the National Center

for Supercomputing Applications (NCSA). The source code as developed and periodically modified by McCool was posted on the web so that users at other sites could download, use, and modify and further develop it.

When McCool departed NCSA in mid-1994, a small group of web masters who had adopted his server software for their own sites decided to take on the task of continued development. A core group of eight users gathered all documentation and bug fixes and issued a consolidated patch. This *patchy* web server software evolved over time into Apache. Extensive user feedback and modification yielded Apache 1.0, released on December 1, 1995.

In the space of four years and after many modifications and improvements contributed by many users, Apache has become the most popular web server software on the Internet, garnering many industry awards for excellence. Despite strong competition from commercial software developers such as Microsoft and Netscape, it is currently in use by about 70% of the millions of web sites worldwide.

Rodeo Kayaking

Rodeo kayaking involves using specialized kayaks to perform acrobatic “moves” or “tricks” such as spins and flips in rough whitewater. Heinerth (2006) reports that the originator of rodeo kayaking was an avid kayaker named Walt Blackader. Blackader was the first to focus in a sustained and serious way on developing methods to “play” in really big whitewater in a kayak. He began evolving his techniques between 1968 and 1970 using standard fiberglass alpine kayaks produced commercially by local manufacturers. Later, other “extreme paddlers” joined him and formed a small community. Additional, similar communities of enthusiasts began to form soon thereafter.

Commercial products developed specifically for rodeo kayaking did not exist for several years. Instead, rodeo kayakers designed and built the specialized kayaks and related gear and safety equipment that they needed for themselves. They also shared their innovation-related information openly with other users who also “built

their own.” With the passage of time, some community members became small-scale user-manufacturers who built copies of their designs for fellow users upon request. Then, as the sport and potential market expanded further, large-scale commercial manufacturing of user-developed kayak designs commenced. By 2002, approximately 50,000 rodeo kayaks were purchased from commercial manufacturers, with many others being “home made.” (Hienerth 2006, Baldwin et al. 2006).

Both of these user innovation networks have evolved and become more complex over time. Today, although they look different on the surface, they are in fact very similar in fundamental ways. Both now include many thousands of volunteer participants. Participants in open source software projects interact primarily via the Internet using specialized websites that volunteer users have set up for their use. Participants in sports innovation networks tend to interact by physically traveling to favorite sports sites and to contests designed for their sport. Most users of open source software simply “use the code,” relying on interested volunteers to write new code, debug others' code, answer requests for help posted on Internet help sites, and help coordinate the project. Similarly, most participants in an evolving sport simply “play the game,” relying on those so inclined to develop new techniques and equipment, try out and improve innovations developed by others, voluntarily provide coaching, and help coordinate network activities such as leagues and contests. Participants that do innovate tend to freely reveal their innovations to all participants, including free riders.

As user innovation networks grow and mature, commercial enterprises attach to or assume complementary roles to user innovation networks. Red Hat and VA Software are well-known examples of commercial involvement in the open source software context. Manufacturers of products first developed and self-manufactured by user-innovators are examples in the case of sports (Shah 2000, Hienerth 2006, Baldwin et al. 2006)

In the remainder of this paper we will explore the phenomenon of and the economics of “user-only” innovation networks by exploring what is known about each of our three basic conditions in turn. We will first review findings on innovation by users (section 2). Next, we will explore findings regarding the free revealing of innovations by users (section 3). Third, we will explore the conditions under which user-self production

can compete with commercial production and distribution (section 4). We then conclude by discussing some implications of horizontal, distributed innovation networks “by and for users themselves” (section 5).

2.0 Condition 1: Some users innovate

Innovation manufacturers rather than innovation users have traditionally been considered the most logical locus of innovation for products and services, because private financial incentives to innovate seem to be higher for them than for individual or corporate users. After all, a manufacturer has the opportunity to sell what it develops to an entire marketplace of users while spreading development costs over a large number of units sold. A user-innovator, on the other hand, can typically expect to benefit financially only from its own internal use of its innovation. Benefiting from diffusion of an innovation to other users in a marketplace has been traditionally assumed to require some form of intellectual property protection followed by licensing. Both matters are costly to attempt, with very uncertain outcomes.

Despite this traditional expectation, empirical studies of the sources of innovation in both industrial and consumer goods fields have shown that in many but not all of the fields studied, users rather than manufacturers are typically the initial developers of what later become commercially significant new products and processes (table 1).

Table 1: Empirical studies of functional sources of commercially-important Innovations

Study	Nature of Innovations and Sample Selection Criteria	Innovative Product Developed by: ^a			
		N	User	Mfr.	Other
Knight (1963)	Computer innovations 1944-1962:				
	- systems reaching new performance high	143	25%	75%	
	- systems with radical structural innovations	18	33%	67%	
Enos (1962)	Major petroleum processing innovations	7	43%	14%	43% ^b
Freeman (1968)	Chemical processes and process equipment available for license, 1967	810	70%	30%	
Berger (1975)	All engineering polymers developed in U.S. after 1955 with > 10 ⁶ lbs. Produced in 1975	6	0%	100%	
Boyden (1976)	Chemical additives for plastics - all plasticizers and UV stabilizers developed	16	0%	100%	

	post World War 2 for use with 4 major polymers				
Lionetta (1977)	All pultrusion processing machinery innovations first introduced commercially 1940-1976 which offered users a major increment in functional utility ^c	13	85%	15%	
Shah (2000)	All important innovations in snowboarding, windsurfing and skateboarding equipment				
	- first of type (e.g., first skateboard)	3	100%	0%	0%
	- major improvements	45	58% ^d	27%	15%
von Hippel (1976)	Scientific instrument innovations:				
	- first of type (e.g., first NMR)	4	100%	0%	
	- major functional improvements	44	82%	18%	
	- minor functional improvements	63	70%	30%	
von Hippel (1977)	Semiconductor and electronic subassembly manufacturing equipment:				
	- first of type used in commercial production	7	100%	0%	
	- major functional improvements	22	63%	21%	16% ^e
	- minor functional improvements	20	59%	29%	12% ^e
VanderWerf (1982)	Wirestripping and connector attachment Equipment	20	11%	33%	56% ^f

^a NA data excluded from percentage computations.

^b Attributed to independent b inventors/invention development companies.

^c Figures shown are based on reanalysis of Lionetta's (1977) data.

^d Includes innovations by users and by "user/manufacturers" that made a small number of copies for others to support their pursuit of their sport (called "lifestyle" firms by Shah).

^e Attributed to joint user-manufacturer innovation projects.

^f Attributed to connector suppliers.

In the specific case of open source software projects, software users are frequent contributors of software code. Thus, Niedner et al (2000) report that contributors of code to open source projects asked to agree or disagree with statements regarding their possible motivations for this ranked gain from "facilitating my work due to better software" as the highest-ranked benefit (average level of respondent agreement with that statement was 4.7 on a scale of 5). Similarly, 59% of contributors to OS projects sampled by Lakhani and Wolf (2005) report that use of the output they create is one of the three most important incentives inducing them to innovate.

Table 2: Proportion of users innovating in diverse product categories

Innovation Area	No. Users Sampled	% Developing and building innovation for own use
Industrial Products		
Printed Circuit CAD	136 user firm attendees at	24.3%

Software (a)	PC-CAD conference	
Pipe Hanger Hardware (b)	74 Pipe hanger installation firms	36%
Library Information Systems (c)	102 Australian Libraries using computerized library information systems	26%
Apache OS server software security features (d)	131 Apache users	19.1%
Consumer Products		
Outdoor Consumer Products (e)	153 outdoor specialty mail order catalog recipients	9.8%
“Extreme” sporting equipment (f)	197 expert users	37.8%
Mountain biking equipment (g)	291 expert users	19.2%
Kitesurfing equipment (f)	157 members of the Australian Kite Surfing Association	28%

Sources of Data: (a) Urban and von Hippel (1988); (b) Herstatt and von Hippel (1992); (c) Morrison, Roberts and von Hippel (2000); (d) Franke and von Hippel (2003); (e) Lüthje (2004); (f) Franke and Shah (2003); (g) Lüthje, Herstatt and von Hippel (2005); (f) Tietz et al (2005).

Studies that have examined the frequency of innovation among user populations have found that user innovation is not a rare event: from 10% to nearly 40% of user respondents report developing a new product for personal or in-house use in fields studied to date (table 2).

These same empirical studies also find that innovation by users tends to be concentrated among “lead users” of the products and processes focused upon. Lead users are defined as users of a given product or service type that combine two characteristics: (1) lead users expect attractive innovation-related benefits from a solution to their needs and so are motivated to innovate, and (2) lead users experience needs that will become general in a marketplace, but experience them months or years earlier than the majority of the target market (von Hippel 1986). Note that lead users are not the same as early adopters of an innovation. They are typically ahead of the entire adoption curve in that they experience needs before *any* responsive commercial products exist – and therefore often develop their own solutions.

2.1 Economics of innovation by users

We have now seen that users do often innovate. Presumably therefore, some users, at least some of the time, must expect innovation to be profitable. Research on innovation-related incentives and capabilities provides a reasonable explanation for the empirical observations regarding innovation by users in general and by lead users in particular. With respect to innovation by users rather than manufacturers, it has been shown that in some product categories users may reasonably expect a higher reward from innovating than can manufacturers. For example, if a user firm develops a new process machine for in-house use that will enable it to be first to market with a major new product line, it may make more profit from that machine than would a manufacturer-innovator (von Hippel 1988).

Second, user innovation costs can be significantly lower than manufacturer innovation costs when the problem-solving work of innovation developers requires access to “sticky”² – costly to transfer - information regarding user needs and the context of use. Such information is located predominantly at user sites and can be most cheaply accessed by problem-solvers located at those sites (von Hippel 1994). Ogawa (1997) has shown that the location of sticky information drawn upon by problem-solvers can significantly affect the locus of innovation. Riggs and von Hippel (1994) have shown that “functionally novel” innovations (which logically are those likely to draw upon a greater proportion of sticky user information) are significantly more likely to be developed by users rather than by manufacturers.

The impact of these two factors on the locus of innovation also allows us to understand and predict that user innovation will *not* be present or will be infrequent in product categories such as engineering plastics (c.f. table 1). Engineering plastics are typically a lower-cost substitute for other engineering materials – a user is seldom

² The stickiness of a given unit of information in a given instance is defined as the incremental expenditure required to transfer that unit of information to a specified locus in a form useable by a given information seeker. When this cost is low, information stickiness is low; when it is high, stickiness is high. A number of researchers have both argued and shown that information required by technical problemsolvers is indeed often costly to transfer for a range of reasons (von Hippel 1994). The requirement to transfer information from its point of origin to a specified problemsolving site will not affect the locus of problemsolving activity when that information can be shifted at no or little cost. However, when it is costly to transfer from one site to another in useable form - is, in our terms sticky - the distribution of problemsolving activities can be significantly affected.

prevented from implementing a desired innovation for lack of a novel engineering plastic. Also, sticky information regarding user needs is not an issue with respect to the development of new engineering plastics: manufacturer-innovators know they will obtain success in the marketplace if they can achieve improvements along dimensions of merit known to be valued by users such as cost or strength of materials.

The concentration of innovation activity among lead users within the user population can also be understood from an economic perspective. Given that innovation is an economically motivated activity (Schmookler 1966, Mansfield 1968), those users expecting significantly higher economic or personal benefit from developing an innovation – one of the two characteristics of lead users – have a higher incentive to and so are more likely to innovate. Also, given that lead users experience needs in advance of the bulk of a target market, the nature, risks, and eventual size of that target market are often not clear to manufacturers. This lack of clarity can reduce manufacturers’ incentives to innovate, and increase the likelihood that lead users will be the first to develop their own innovative solutions for needs that later prove to represent mainstream market demand (Franke et al. 2006).

In the specific instance of open source software, software users can profit by using the software improvements that they develop. In contrast, there is no commercial market for open source software – because open source software developers make their innovations freely available as a public good. This eliminates manufacturers’ direct path to appropriating returns from private investment in developing open source products. Recall, however that manufacturers may find indirect paths to profiting from open source software projects and so may contribute to them. For example, Red Hat profits by distributing and providing support services for many open source software programs. IBM profits by selling proprietary software and hardware that complements open source software programs like GNU/Linux.

3.0 Condition 2: Some users freely reveal

We next turn to exploring users’ options with respect to reaping profits from their innovations. Users in principle have a choice among three such options: they may license their innovation to others (and/or “license to themselves” and manufacture their innovation for the market); they may keep it secret and profit from in-house use; or they

may choose to “freely reveal” their innovation-related information so that others may replicate the innovation if they wish to do so.

When we say that an innovator freely reveals proprietary information, we mean that all existing and potential intellectual property rights to that information are voluntarily given up by that innovator and all interested parties are given access to it – the information becomes a public good. Thus, free revealing of information by a possessor is defined as the granting of access to all interested agents without imposition of any direct payment. For example, placement of non-patented information in a publicly-accessible site such as a journal or public website would be free revealing under this definition (Harhoff et al, 2003).³ (Revealing of open source software is not quite free according to this stringent definition, but the economic effects are similar. Licenses granted to users of open source software do place some constraints upon adopters in order to forestall possible strategies that could result in “taking the code private” (O’Mahoney 2003).)

Empirical studies show innovating users often choose to freely reveal detailed information sufficient to reproduce their innovations to other users and to manufacturers as well. Von Hippel and Finkelstein (1979) found this practice among users of clinical chemistry analyzer equipment produced by the Technicon Corporation; Allen (1983) found furnace design information openly revealed by iron producers in the 19th century iron-making industry, Lim (2000) reports that IBM freely revealed information on its “copper interconnect” semiconductor process and equipment innovations to equipment manufacturing firms and thereby to competing users; Morrison et al (2000) found

³ “Freerevealing” as so defined does not mean that recipients necessarily acquire and utilize the revealed information at no cost to themselves. Recipients may, for example, have to pay for a journal subscription or an Internet connection or a field trip to acquire the information being freely revealed. Also, some may have to obtain complementary information or other assets in order to fully understand that information or put it to use. However, if the information possessor does not profit from any such expenditures made by information adopters, the information itself is still freely revealed, according to our definition. Conversely, note that innovators may sometimes choose to subsidize the acquisition and evaluation and use of their freely-revealed information by others. For example, a firm may invest in extensive and expensive lobbying to get others to adopt a technical standard it has developed. Similarly, writers of computer code that they freely reveal may work very hard to document their code in a way that is very easy for potential adopters to understand. Such subsidization efforts do not affect the status of the information itself as being freely revealed according to our definition.

improvements to library information software freely revealed by libraries; Franke and Shah (2003) found the detailed design of user-developed innovations being freely revealed within communities of sports enthusiasts. And, of course, contributors to open source projects are also known to freely reveal the novel software code they have developed at private expense to fellow innovators and to free riders on equal terms (e.g., Raymond 1999, Lerner and Tirole 2002).

Free revealing of innovation-related information can be the dominant way innovations are diffused in some fields and under some conditions. Thus, Franke and Shah (2003) studied patterns of user innovation sharing in four communities of serious sports enthusiasts. Innovators in these communities quite universally agreed with the statement that they shared their innovation with their entire community free of charge – and strongly disagreed with the statement that they sold their innovations ($p < 0.001$, t-test for dependent samples)

3.1 Economic case for free revealing

To economists, free revealing of innovation-related information is surprising, because it violates a central tenant of the economic theory of innovation. In this classical view, appropriating returns to innovation requires innovators to keep the knowledge underlying an innovation secret or to protect it by patents or other means. After all, non-compensated spillovers of innovation-related information should represent a loss that innovators would seek to avoid if at all possible, even at some cost. Why then do we observe that some innovation-related information is voluntarily freely revealed?

In this section, we briefly summarize available empirical studies and conclude that this question should be turned on its head: Why did we ever think that free revealing of innovation-related information would not be common? Extant studies show that it is often not practical to benefit from intellectual property via either licensing or secrecy – even if innovators should wish to do this. Existing research also shows how innovators can often obtain private benefits from free revealing. When benefits from free revealing exceed the benefits that are *practically* obtainable from licensing or secrecy, then free revealing should be the preferred course of action for a profit-seeking firm.

General impracticality of licensing and trade secrecy

To license their intellectual property, innovators must first gain some form of legal protection for it. In most subject matters, the relevant form of legal protection is the patent grant, generally the “utility” patent (design and plant patents also exist).⁴ Are patents an effective form of protection for innovators? The available empirical literature suggests, first, that innovators do not generally think that patents offer a very effective form of protection for intellectual property. A study by Scherer (1959) found only eight of thirty seven respondents (“executives responsible for technical change”) reporting that patents were ‘very important’ to their companies (Scherer 1959, 117). This result is especially interesting because Scherer selected his sample only from the firms which presumably value patents most highly - those which hold a large number of them. A similar finding was reported by Taylor and Silberston (1973), who report that 24 of the 32 responding firms said that 5 percent or less of recent R&D expenditures would not have been undertaken if patent protection had not been available (ibid, p. 30). Levin et al (1987) conducted a survey of 650 R&D executives in 130 different industries, and found that all except respondents from the chemical and pharmaceutical industries judged patents to be “relatively ineffective.” Similar findings are reported by Mansfield (1968, 1985) and reaffirmed by Cohen et al. (2000).

Consider finally the practicality of protecting an innovation as a trade secret. As was the case with patents, much intellectual property does not qualify for protection as a trade secret because it cannot simultaneously be kept secret and exploited for economic gain. All innovators can in principle keep product innovations secret while developing them and before putting them on the market. However, once the product is on the market, the trade secrets it contains can generally be legally discovered by those skilled in relevant arts and so lose their status as trade secrets. User-innovators have the additional possibility of benefiting for an indefinite period from the *process* innovations they develop while keeping them secret behind their factory walls. However, trade secrets are not likely

⁴ Tradeseccy law is a form of protection applicable to innovation that can be kept secret. Tradeseccy can in principle be licensed to others that will maintain the secret status of the information revealed to them under license. But licensing tradeseccy is often impractical. The owner must at least partially reveal the secret to potential buyers so that they may evaluate their potential purchase. This incurs the risk of the secret becoming widely known, thus losing both its status as a tradeseccy and its value to a potential licensee. In the special case of software innovations (considered a form of “writings”) copyright protection is applicable and widely used.

to remain secrets for long. Mansfield (1985) studied a sample of 100 American firms and found that the period during which intellectual property can be kept secret in fact appears to be quite limited. He reports that "...information concerning development decisions is generally in the hands of rivals within about 12 to 18 months, on the average, and information concerning the detailed nature and operation of a new product or process generally leaks out within about a year."⁵

(Software is a special case and better positioned than most other fields with respect to the feasibility of establishing a level of legal protection that can support the licensing of intellectual property. This is due to the legal status of software as "writings," which can be protected by copyright. Copyright is a low cost and immediate form of legal protection – it is applicable to many forms of original writings and images and "follows the author's pen across the page." Licensing of copyrighted software is widely practiced by commercial software firms. When one "buys" a copy of a non-custom software product one is typically actually buying only a license to use that software rather than buying the intellectual property itself. Copyright licensing is also the basis of free and open source software practice. The rights that open source software users enjoy are conveyed to them by the software authors. These authors use their own copyright to grant licenses to users that allow them to use, study, modify and distribute their code (see footnote 1).

Sources of benefit from free revealing

Our discussions of the applicability of patent protection and trade secrecy protection to intellectual property appear to in most instances leave the innovator with only the choice between voluntary free revealing of innovation-related information now and involuntary free revealing later. Given this choice, why should user-innovators choose

⁵ In addition, a user-innovator may not be the only holder of "its" secret. Note in this regard that Rosenberg (1976) has shown that important innovations often come from outside of the industry of application. When this is so, and when innovations diffuse from one industry to another with a lag, it is likely that competing firms in the originating industry all will know the information and so incur no competitive loss relative to their rivals by revealing it to firms in other industries.

If research shows that an innovator's secret information is also frequently known by others, then all must estimate that the actual likelihood of keeping the information secret depends on the choice made by the possessor with the least to lose (or most to gain) from revealing it. If a holder of the secret judges that other possessors are likely to reveal it if they don't, any preference that they might have to hide their information is rendered moot.

to voluntarily free reveal now? This matter is reviewed in Harhoff et al (2003) and von Hippel (2005) in detail. We provide brief overview here. Allen (1983) argued that free revealing could be economically justified by profit-seeking firms on several grounds: (1) gains in reputation for the firm or firm managers are sufficient to offset a reduction in firm operating profits caused by free revealing; (2) so many people knew the information that it could not have been kept secret in any case; (3) the innovation is to some extent specific to the innovator and so free riders would not gain advantage equal to that of the innovator; (4) gains in the value of assets complementary to the use or production of the innovation exceed losses associated with free revealing; (5) free revealing may increase the innovator's profit by enlarging the overall market for the product under consideration.

An additional class of incentives for free revealing of innovation-related information involves the increased diffusion of innovations for which this has been done. Of course, more than innovation-related information is required to induce imitation - there must be an incentive to imitate and needed skills as well (Dosi 2006, 1982). However, free information *is* important, and when an innovating user freely reveals information sufficient to reproduce an innovation, one result is to increase the diffusion of that innovation relative to what it would be if the innovation were either licensed at a fee or held secret. The innovating user may then benefit from the increase in diffusion via a number of effects. Among these are network effects, reputational gains, and related innovations induced among and revealed by other users. In addition, an innovation about which information has been freely revealed can become an informal standard that may preempt the development and/or commercialization of other versions of the innovation. If, as was suggested by Allen, the innovation about which information has been revealed is designed in a way that is especially appropriate to conditions unique to the innovator, this can result in creating a permanent source of advantage for that innovator. Note that being first to reveal information regarding a given type of innovation increases a user's chances of having *its* innovation widely adopted, other things being equal. This may induce innovators to race to reveal first.

Incentives to freely reveal innovation-related information have been explored in the specific context of open source software by Raymond (1999), Lerner and Tirole (2002) and others. Incentives proposed include the likelihood that free revealing of quality code can increase a programmer's reputation among peers and also among potential employers

– thus increasing his or her value on the job market. Firms may also benefit from a reputation of being an employer of contributors to open source software projects. (To the extent that the incentives of employer and employee differ on this matter, there will be agency issues.) It has also been found that the cost disadvantage as perceived by innovators relative to free riders is likely to be low. Those who contribute code to open source projects report that they benefit from the work of coding itself in terms of both enjoyment and learning (Lakhani and Wolf 2005). These process benefits remain private even when the output of the process – the software code itself – is freely revealed (von Hippel and von Krogh 2003). Finally, a number of writers have proposed that communal norms, including altruism, may play a strong role in inducing free revealing of information in the field of open source software. For example, programmers may feel incited by “generalized reciprocity” (Ekeh 1974) to reveal their code because they have benefited from the code freely revealed by others.

Losses to innovators from free revealing come from the opportunity cost of not licensing or selling their software plus any advantage this action provides to competitors that free-ride on the innovation. With respect to the latter, the stronger the competition between the user-innovator and other users of the innovation, the larger will be the loss of competitive advantage that the innovator incurs by revealing innovation-related information. Conversely, when competition between innovation users is low, e.g. due to geographical separation of markets, the revealing user does not suffer as a consequence of the advantages he provides to others.

The negative impact of competition on users’ willingness to free reveal has been documented by Franke and Shah (2003). Free revealing in the *absence* of competition has been explored by Morrison et al (2000) and found to be high. These authors studied innovation sharing by Australian libraries that had made innovative modifications to their computerized library information systems (OPACs). The libraries studied were not competitors in the marketplace: all were non-profit organizations and, although their budgets were probably partially determined by the number of patrons they attracted, they served markets that were non-overlapping with respect to geographic coverage and/or subject matter. Morrison et al found that users had shared 56% (22 of the 39) of the OPAC modifications they had developed with manufacturers and/or or users. Forty four percent had not been shared. The reasons for not sharing were found unrelated to

competitive issues. Instead, study participants ascribed the fact that they had not shared some innovations to the lack of a convenient forum for doing so, and/or to their supposition that others would not have an interest in a given innovation.

4.0 Condition 3: Users can self-manufacture their innovations “cheaply”

Our third and final condition for the emergence and successful functioning of horizontal, user-*only* innovation networks was that innovation replication by users (user-self production) can compete with commercial production and distribution. To achieve this in the case of information products simply requires the diffusion of complete products from the innovating users to others via the Internet or similar low-cost means. In this case identical, essentially costless means of reproduction and distribution are available to and employed by both information product manufacturers and information product users – and so horizontal networks of users do not *require* the involvement of manufacturers in these tasks. In the case of physical products, the low cost diffusion of innovation-related information from the innovating user to others similarly can be accomplished by users only.⁶ But economies of scale are often involved in the production of copies of the physical innovation. This can mean that horizontal user innovation networks do require the involvement of manufacturers for the economical reproduction of physical product user innovations.

⁶ It is important to note that alternate low cost methods for diffusing innovation-related *information* exist in many fields that are *not* dependent on the Internet. Consider that those who share an interest in a physical or information product may physically meet for a range of purposes such as conferences or contests. When this is so, costs of innovation-related information diffusion can be *episodically* very low. Innovators can store their innovations for occasional batch networking and diffusion at low incremental cost, since the cost of coming to such a physical meeting has already been incurred. In these face-to-face settings, some information transfers are easily effected that would be difficult to transact over the Internet. As an example, consider again the rodeo kayaking innovation history we summarized at the start of this article. In that case fellow rodeo kayaking enthusiasts often gathered together physically to enjoy their sport together, and to engage in competitions. While at such meetings, they could transfer complex, poorly-encoded information in very low-cost, multimodal manner: “Watch how I do *this*,” and “Run your hand along *this* curve I added to my kayak hull – I think it makes all the difference for doing the type of flip I just showed you! Try it yourself while I watch and comment.”

4.1 Economics of user self manufacture of physical products

Recall that we have proposed that user-only innovation development, production, distribution and consumption networks can flourish when (1) at least some users have sufficient incentive to innovate, (2) at least some users have an incentive to voluntarily reveal their innovation-related information, and (3) user-self production can compete with commercial production and distribution. When only the first two conditions hold, we proposed that a pattern of user innovation and trial will occur within user networks, followed by commercial manufacture and distribution of innovations that prove to be of general interest. In the case of physical products, we suggest that there are two types of circumstances in which condition 3 will hold: first, when production volumes required are very small; second, when *no* model-specific investments are required to manufacture the innovation.

With respect to the first circumstance, Baldwin et al. (2006) pointed out that at low production volumes, users and manufacturers frequently use the same low fixed-cost, high variable-cost production technologies. When this is so, manufacturers will not necessarily be able to replicate physical products more cheaply than will individual self-manufacturing users. The illustration used by Baldwin et al. with respect to this point was the manufacture of rodeo kayaks. (Recall from earlier in the paper that rodeo kayaking is a sport involving the use of specialized "rodeo kayaks" to perform acrobatic tricks such as spins and flips in rough whitewater.) For many years, both users and manufacturers produced rodeo kayaks via identical, hand manufacturing methods. These methods involved the hand "lay-up" of fiberglass matting, followed by coats of liquid plastic also applied by hand. Under these circumstances, user and manufacturer production costs were probably very similar.

With respect to the second circumstance, consider that user innovators that develop, produce and distribute innovations within horizontal, user-only innovation networks usually do these things by drawing upon inputs and platforms that incorporate commercially-manufactured items. For example, users of open source software users that develop and distribute novel software via the Internet “from user to user” are relying on a platform constructed from many manufactured components— such as routers and optical fibers. Similarly, users that are developing physical products in a “user-only network” buy standard manufactured input materials and process tools to create their self-manufactured products. Thus, user self-manufacturers of rodeo kayaks use commercially-manufactured glass matting and liquid plastics and various types of process tools and equipment to produce them. The distinction that applies to make all of these innovations producible and distributable by “user only” is that all *innovation-specific* investments and activities are carried out by users only in these cases. *Pre-existing* processes and tools and input materials produced by manufacturers as standard products may be applied by users during the course of these innovation-specific activities.

Interestingly, as the use of mass customization factory methods become available to more fields, the concentration of innovation-specific investments and activities within horizontal user-only networks may apply to more product types and be competitive with production involving innovation-specific investments by manufacturers at steadily higher unit volumes. (So called “mass-customized” production methods are based on computer-driven production tools that can be automatically adjusted to produce down to single units of unique products at variable costs similar to those achievable by fixed, model-specific production tooling (Pine 1993).) For example, if users can someday “print” a copy of a rodeo kayak on the same adjustable mass-customization process machines as manufacturers would use to achieve the same production task at larger market volumes, then it would seem reasonable that horizontal, user-only innovation networks will someday exist in the case of physical products as well as information products independent of market size.

5.0 Discussion and suggestions for further research

We have now seen that conditions favorable to horizontal, user innovation networks may exist in many fields. That is: users do frequently innovate in many fields,

and these users appear to often have the incentives to freely reveal innovation-related information and means for innovation replication and distribution that are cost-competitive with those available to manufacturers as well.

In this paper we have focused on exploring why users in particular might innovate and then freely reveal their proprietary information on user innovation networks rather than attempt to hide or license that information. We have adopted this relatively narrow focus because it seems to us to be interesting and important to explore how and why innovation networks run exclusively for and by users function. Such networks offer the interesting prospect of direct user to user innovation processes that can dispense with manufacturers as intermediaries. It has been found that when users can innovate for themselves to create precisely what they want, rather than being restricted to a set of options on offer that have been created by others, their satisfaction is significantly higher. For example, Franke and von Hippel (2003) studied the relative satisfaction levels of a sample of users of Apache open source security software. Controlling for levels of user programming skill, they found that users that had written new code to fit Apache more precisely to their needs were significantly more satisfied.

There are many issues to explore if we wish to better understand the nature and potential of horizontal user innovation networks. In addition to appropriate incentives, horizontal innovation networks must also have the appropriate problem-solving capabilities. Dosi et al (2000) discuss the notion of organizational capabilities, and it would be interesting and useful to extend this discussion to explore the capabilities enabled by and valuable to horizontal innovation networks. Henkel and von Hippel (2005) have found that social welfare is increased when users *and* manufacturers innovate as relative to a world in which only manufacturers innovate. It would clearly be useful to further develop the social welfare benefits associated with user innovation networks. As a related matter, it would also be useful to consider the implications for public policy related to intellectual property if such networks prove to offer social welfare benefits.

Both of the early-stage user networks that we described at the start of this paper – the first in open source software and the second in sports - were user-only with respect to both innovation development and diffusion at their start. At later stages product manufacturers began to make contributions as well, as the possibilities for profit became clear to them. It may well be that new projects characteristically begin as pure user

innovation networks, and that later manufacturers begin to participate. An initial exploration and modeling of this pattern has recently been done by Baldwin et al. (2006)

The concept of horizontal, user-only innovation networks that we have considered in this paper can be extended to the more general category of user *content* networks. As is the case for user innovation networks, user content networks offer content that users either post as of interest to others and/or questions that users post to the network for a possible answer. Such content networks exist in both user-founded and run and commercial forms. Prominent examples can be found in the medical field in the form of specialized websites where patients and others are free to both post and download information on specific medical conditions. Many variations on commercially-supported user content networks also exist. Zagat.com is a website offering a compilation of restaurant evaluations by ordinary consumers that can be freely downloaded; Allexperts.com is a website offering free access to self-described experts who will provide information upon request. When the service provided by such networks is simply to offer non-proprietary “content” in a more convenient and accessible form rather than to diffuse valuable innovations about which information been freely revealed, the arguments for participation by users and others gets considerably simpler. One need consider only the costs and benefits associated with diffusion and not issues related to loss of proprietary intellectual property associated with the free revealing of innovation-related information.

User innovation networks assume various forms, and it will be useful to explore the conditions appropriate for each, and the costs and benefits that each provide. For example, as was noted earlier, user innovation networks may, but need not, incorporate the qualities of user “communities” for participants, where these are defined as “... networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity.” (Wellman 2002 p. 4). It will be important to explore the nature and functioning of these communities further. Some recent work on this topic has been conducted by Antorini (2005) and by Jeppesen (2004).

In sum, it appears that conditions favorable to horizontal user innovation networks often exist today, and that technological advances over time will make conditions more favorable still. It also appears likely that horizontal innovation networks, by and for users, both increase individual freedom of choice with respect to products and services and

increase social welfare. An improved understanding of this type of network seems well worth striving for.

References

Allen, Robert C. "Collective Invention." Journal of Economic Behavior and Organization 4, no.1(March 1983):1-24.

Antorini, Y. M. (2005). "The Making of a Lead User. The Case of Adult Fans of LEGO." *Copenhagen Business School*. Working Paper.

Baldwin, Carliss Y., Christoph Hienerth and Eric von Hippel (2006) "The migration of products from lead user-innovators to manufacturers," *Research Policy*, *forthcoming*

Berger, Alan J. (1975) "Factors Influencing the Locus of Innovation Activity Leading to Scientific Instrument and Plastics Innovation." Unpublished S.M. thesis, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass.

Boyden, Julian W. (1976) "A Study of the Innovative Process in the Plastics Additives Industry." Unpublished S.M. thesis, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass.

Cohen, W.M., Nelson, R.R., and Walsh, J.P. (2000) "Protecting their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or not)," NBER Working Paper 7522.

Dosi, Giovanni (1993) "Technological Paradigms and Technological Trajectories. A Suggested Interpretation of the Determinants and Directions of Technical Change", *Research Policy* Vol 22 No.2 (April) p. 102 ff

Dosi, Giovanni, L. Marengo and C. Pasquali (2006) "How much should society fuel the greed of innovators? On the relations between appropriability, opportunities and rates of innovation." (July) *Research Policy*, *forthcoming*

Dosi, Giovanni, R. Nelson and S. Winter (eds.), *The Nature and Dynamics of Organizational Capabilities*, Oxford/New York, Oxford University Press, 2000

Ekeh, P. P. (1974). *Social Exchange Theory: The Two Traditions*. Cambridge, MA: Harvard University Press.

Enos, John Lawrence. Petroleum Progress and Profits: A History of Process Innovation. Cambridge Mass.: MIT Press, 1962.

Franke, Nikolaus, Eric von Hippel and Martin Schreier (2006) "Finding Commercially Attractive User Innovations: A Test of Lead-User Theory" Journal of Product Innovation Management Vol 23 pp. 301-315.

Franke, Nikolaus and Sonali Shah (2003) "How Communities Support Innovative Activities: An Exploration of Assistance and Sharing Among End-Users." Research Policy 32 (1) p. 157-178.

Franke, Nikolaus and Eric von Hippel (2003), "Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software" Research Policy Vol 32, No. 7, (July) pp.1199-1215.

Freeman, C. "Chemical Process Plant: Innovation and the World Market." National Institute Economic Review 45 (August 1968):2957.

Harhoff, Dietmar, Joachim Henkel and Eric von Hippel (2003) "Profiting from voluntary information spillovers: How users benefit from freely revealing their innovations," *Research Policy* vol 32, No.10 (December) pp.1753-1769

Henkel, Joachim and Eric von Hippel (2005) "Welfare Implications of User Innovation," *Journal of Technology Transfer* Vol 30 Nos. 1-2 (January) Pages 73-87.

Herstatt, Cornelius, and Eric von Hippel (1992), "From Experience: Developing New Product Concepts Via the Lead User Method: A Case Study in a "Low Tech" Field", Journal of Product Innovation Management, 1992; 9: 213-221.

Hienerth, Christoph (2006) "The commercialization of user innovations: the development of the rodeo kayaking industry" *R&D Management* 36 3 pp. 273-294.

Jeppesen, L. B. (2004). "Profiting from Innovative User Communities: How Firms Organize the Production of User Modifications in the Computer Games Industry." *Department of Industrial Economics and Strategy, Copenhagen Business School, Copenhagen, Denmark*. Working paper WP-04.

Knight, Kenneth E. "A Study of Technological Innovation: The Evolution of Digital Computers." Unpublished Ph.D. dissertation, Carnegie Institute of Technology, Pittsburgh, PA., 1963.

Lakhani, K. R. and B. Wolf (2005). "Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open Source Software Projects." In: J. Feller, B. Fitzgerald, S. Hissam, and K.R. Lakhani (eds.), *Perspectives on Free and Open Source Software*. Cambridge, MA: MIT Press.

Lerner, J. and J. Tirole (2002). "Some Simple Economics of Open Source." *Journal of Industrial Economics* 50(2): 197-234.

Levin, Richard C., Alvin K. Klevorick, Richard Nelson and Sidney G. Winter (1987), "Appropriating the Returns from Industrial Research and Development", *Brookings Papers on Economic Activity*, Vol. 3, pp. 783-831.

Levy, Steven (1984) *Hackers*, New York: Anchor/Doubleday

Lim, Kwanghui (2000), "The Many Faces of Absorbitive Capacity: Spillovers of Copper Interconnect Technology for Semiconductor Chips," MIT Sloan School of Management Working paper # 4110

Lionetta, William G., Jr. "Sources of Innovation Within the Pultrusion Industry." Unpublished S.M. thesis, Sloan School of Management, Massachusetts Institute of

Technology, Cambridge, Mass., 1977.

Lüthje, C. (2004). "Characteristics of Innovating Users in a Consumer Goods Field: An Empirical Study of Sport-Related Product Consumers." *Technovation* (September)

Lüthje, Christian, Cornelius Herstatt and Eric von Hippel (2005), "User-innovators and "local" information: The case of mountain biking," *Research Policy*, Vol 34, No. 6 (August) pp. 951-965.

Mansfield, Edwin (1968) *Industrial Research and Technological Innovation: An Econometric Analysis*. New York: W.W. Norton.

Mansfield, E. (1985). "How Rapidly Does New Industrial Technology Leak Out?," *Journal of Industrial Economics*. Vol. 34, pp. 217-223.

Morrison, Pamela D., John H. Roberts and Eric von Hippel (2000), "Determinants of User Innovation and Innovation Sharing in a Local Market," *Management Science*, 46, 12 (December), pp1513-1527.

Niedner, Sven, Guido Hertel and Stefanie Hermann, (2000) "Motivation in Open Source Projects," <http://www.psychologie.uni-kiel.de/linux-study/>

Ogawa, Susumu (1997), „Does sticky information affect the locus of innovation? Evidence from the Japanese convenience-store industry“ *Research Policy* Vol. 26, pp. 777-790.

O'Mahony, S. (2003). "Guarding the Commons: How Open Source Contributors Protect their Work." *Research Policy* 32(7): 1179–1198.

Pine, J. B. II. (1993). *Mass Customization: The New Frontier in Business Competition*. Boston, MA: Harvard Business School Press.

Raymond, Eric S. (1999), *The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*, (Cambridge: O'Reilly)

Riggs, William and Eric von Hippel (1994), "The Impact of Scientific and Commercial Values on the Sources of Scientific Instrument Innovation," *Research Policy* 23 (July): 459-469.

Rosenberg, Nathan "Technological Change in the Machine Tool Industry, 1840-1910," *Perspectives on Technology*, Cambridge, 1976, chapter 1; also see "Uncertainty and Technological Change," in Landau, Taylor and Wright, *The Mosaic of Economic Growth*, Stanford 1996, esp. pp. 345-47.

Scherer, F. M. et al. (1959), *Patents and the Corporation*, 2nd ed. Boston: James Galvin and Associates.

- Schmookler, Jacob. Invention and Economic Growth. Cambridge, Mass.: Harvard University Press, 1966.
- Shah, Sonali (2000) "Sources and Patterns of Innovation in a Consumer Products Field: Innovations in Sporting Equipment" Sloan Working Paper #4105 (May)
- Taylor, C. T. and Z.A. Silberston (1973) The Economic Impact of the Patent System: A Study of the British Experience Cambridge: Cambridge University Press.
- Tietz, Robert, Pamela Morrison, Christian L uthje and Cornelius Herstatt (2005), "The process of user-innovation: a case study in a consumer goods setting." International Journal of Product Development, Vol 2, No. 4, pp. 321-338.
- Urban, Glen L., and Eric von Hippel (1988), "Lead User Analyses for the Development of New Industrial Products," Management Science 34, no. 5 (May):569-82.
- VanderWerf, Pieter A. "Product tying and innovation in U.S. wire preparation equipment," *Research Policy* 19 (1990): 83-96.
- von Hippel, Eric (1977) "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation," *IEEE Transactions on Engineering Management* EM-24, no. 2 (May):60-71.
- von Hippel, Eric (1976) "The Dominant Role of Users in the Scientific Instrument Innovation Process," *Research Policy* 5, no. 3 (July):212-39.
- von Hippel, Eric (1988) *The Sources of Innovation* (New York: Oxford University Press).
- von Hippel, Eric (2005) *Democratizing Innovation* (Cambridge: MIT Press).
- von Hippel, Eric (1994) "Sticky Information" and the Locus of Problem Solving: Implications for Innovation" *Management Science* 40, no.4 (April): 429-439.
- von Hippel, E. and S. N. Finkelstein (1979), "Analysis of Innovation in Automated Clinical Chemistry Analyzers," *Science & Public Policy*, 6, 1, 24-37.
- von Hippel, Eric and Georg von Krogh (2003), "Open Source Software and the "Private-Collective" Innovation Model: Issues for Organization Science" *Organization Science* 14 (2) 208-223.
- Wellman, Barry, Jeffrey Boase and Wenhong Chen (2002) "The Networked Nature of Community On and Off the Internet" Working paper, Centre for Urban & Community Studies, University of Toronto (May)