# User Innovation

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## Summary and Keywords

Users of products and services, be they user firms or consumers, frequently develop innovations for their own benefit. Such user innovation is a long-existing phenomenon, but it has gained much momentum in the new millennium. The Internet has greatly facilitated connections between creative users, and at the same time cost-effective design and prototyping technologies are making it increasingly feasible for users to develop their own products and services.

Users have been found to innovate mainly because they want solutions that best serve their own needs. In general, their innovation activities involve no expectations of monetary profit, being motivated rather by self-rewards (such as fun, positive feelings of altruism, signaling of competence to the community of peers). This explains why users are typically willing to share their innovations without requiring payment. A problem of user innovation is that, since the benefit that others could gain is an externality for users, they lack strong incentives to invest in the active diffusion of their innovations. The consequence of this “diffusion shortfall” is social welfare losses.

There are several ways in which producers and service providers can help overcome these problems and benefit from the innovation potential of users at the same time. They can apply the lead user method to actively search for a small group of particularly highly motivated and qualified users, they can outsource product design work to their users via user design toolkits, and they can broadcast innovation challenges to an appropriate crowd of external problem solvers.

Keywords: innovation, user innovation, open innovation, sources of innovation, motivations, diffusion of innovations, lead user, toolkits for user innovation, crowdsourcing

# Users Innovate

When considering the innovation capabilities of users, many managers adopt what could be termed the “Ford attitude.” According to the legendary founder of the automobile multinational, “If I had asked people what they wanted, they would have said: faster horses.” This pessimistic assessment of users’ ability to contribute to innovation seems still to

be widespread among market experts and managers involved in innovation. However, research on the sources of innovation has shown that it does not reflect users' real innovation-related capabilities.

Innovations by users represent a primeval and archetypical mode of innovation: if one has a problem, one tries to fix it. Before the earliest forms of barter and trade emerged, practically all innovation was developed by users. It is difficult to imagine prehistoric humans inventing the fire, the hand-ax, or pottery for commercial purposes. However, as a result of division of labor, industrialization, and the increasing complexity of technology and production processes, firms with specialized R&D departments and professional innovation functions have undoubtedly played a key role in the generation of innovations. Since such firm-based activities seem to form the main focus of scholarly research on innovation management, the impression has emerged that the dominant (or even the only) mode is producer innovation: that innovation projects are initiated and executed by entities that expect to generate profits by selling the new product or service, not by using it. The economic basis for this view is the notion of scale effects (Baldwin & von Hippel, 2011). Evidently, the expected benefit obtained by selling a newly developed standard product or service to many customers in a market is higher than that obtained by an individual user from the use of their innovation. In addition, a producer selling to many customers can invest considerably more resources in innovation projects than an individual user could devote. Thus, theoretically, user innovations should barely exist, at least in industrialized and developed economies.

However, users have actually been very active in innovation work, as is evident from the abundant anecdotal evidence of major first-of-type innovations originating from users. The first airplane, the Internet, the surfboard, the heart-lung machine, the baby stroller—these are just a few of the many products that originated not from firms seeking to obtain profits via selling but from users seeking to benefit from using. Indeed, in addition to a high number of documented examples, there is an increasing body of systematic empirical research showing that user innovation is a frequent phenomenon.

Researchers have studied nationally representative samples of (end-)users and analyzed the proportion of them having developed new products or innovative product modifications for personal use in the previous three years. Studies of this type on the frequency of user innovation have been conducted in Canada, China, Finland, Japan, South Korea, Russia, Sweden, the United Kingdom, the United Arab Emirates, and the United States. These surveys document percentages of innovating users ranging between 1.5 and 9.6% (see the overview in Jin, Su, de Jong, & von Hippel, 2018). This implies that hundreds of millions of user innovators exist in the population worldwide. While these numbers indicate a very high activity level involving millions of person-days spent on development, they may still be a conservative measure of the level of user innovations. There is reason to believe that users tend to underestimate their innovation activities when they are asked to report them in surveys and interviews (Franke, Schirg, & Reinsberger, 2016).

The finding that user innovation is a frequent behavior does not necessarily mean that it is of economic importance. User innovations might generally be “small potatoes”: minor adaptations of limited value for other users. Thus, a second strand of studies has investigated the economic value of user innovations in different technological fields and industries. By analyzing trade publications and conducting interviews with industry experts, researchers have identified the most important innovations within the focal field and searched for the entities that created the first functioning prototypes. The stable finding across 21 different areas—including financial services, medical apps, off-label drug therapies, scientific instruments, and sports equipment—is that up to 87% of the most important innovations were originally developed by users (see the overview in Bradonjic, Franke, & Lüthje, 2019). Overall, research results suggest that the majority of fundamental innovations in a great variety of industries are the work, not of producers, but of users.

A number of arguments make it plausible that user innovation has become both more frequent and more important and that these trends will continue in the future. Above all, the Internet and online social networks have enabled individuals to exchange information much more easily than in times when contacts were primarily restricted to family, friends, neighbors, and work colleagues. Geographical and social barriers have been weakened, and users now have easy access to like-minded people around the globe with complementary skills. It is thus quite simple for individual innovators to join forces by pooling their creativity, their knowledge, and their technical capabilities. The resulting groups or communities of users have the resources to accomplish major innovative developments. There are countless examples of user innovations that have been enabled by collaboration via the Internet, with the most prominent cases being open source software projects like Linux, Apache, or Firefox, and digital platforms based on user-generated content like Wikipedia and YouTube.

Developments in information technology have also made available many tools that assist and support the individual user in actively converting an idea into a product. The technology of additive manufacturing (commonly known as “3D printing”) enables physical prototypes of functional designs to be generated, or customized products to be printed, without incurring prohibitively high costs (Weller, Kleer, & Piller, 2015). Some projections suggest that the vast majority of consumers will have additive manufacturing printers at home by the year 2030 (Jiang, Kleer, & Piller, 2017). Today, personal computers, general purpose software, and specialized software applications for writing texts, doing calculations, creating designs, and assembling machinery are cheap and easy to handle and thus greatly decrease the costs of innovating for users. For example, at the end of the 20th century, recording a self-created song required not only musical talent but also access to an expensive studio and a professional producer, as well as involving the costly manufacture of physical products (vinyl records, tapes and CDs). Today, digitalization means that recording can be done with a PC at home, while the song can be brought to the public via the Internet. Consequently, the costs of music production and distribution have been dramatically reduced.

# Definitions: Who Are “Users” and What Is an “Innovation”?

The sources of innovation can be categorized by their functional relationships to the new products and services (von Hippel, 1988). “Users are . . . firms or individual consumers that expect to benefit from *using* a product or service. In contrast, manufacturers expect to benefit from *selling* a product or a service” (von Hippel, 2005, p. 3). Innovating users can exist in both B2C (consumers, households) and B2B (firm users, professional users) settings. Self-evidently, most consumers primarily derive benefit from using the consumer goods that they purchase and can therefore be classified as end users. The vast majority of firms are users, too, as they apply technology, machines, software, vehicles, and so on to produce the products and services they supply to others.

Innovating means creating a functional, novel prototype that is put to use. This definition does not fully conform to the traditional understanding of what differentiates an innovation from an invention. Most older definitions require a form of commercial exploitation, most notably introduction into product or service markets, as a requirement to call something an innovation (Berry & Taggart, 1994; Freeman, 1982; O’Sullivan & Dooley, 2009; Roberts, 1988). They thus exclude non-commercial innovations by definition. For example, the development of the functionally novel online encyclopedia Wikipedia would not qualify as an innovation because accessing and reading it is free. This explains why user innovation was excluded from most national statistics on innovation activities and thus neglected from policymakers. In this article we follow the broadly accepted definition of innovation in the Oslo Manual (OECD/Eurostat, 2018). Since its amendment in the year 2018, this no longer requires a novel product or service to be commercialized on markets for it to be classified as an innovation (Gault, 2018; von Hippel, 2017). The new version is as follows (OECD/Eurostat, 2018):

> An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). The generic term “unit” describes the actor responsible for innovations. It refers to any institutional unit in any sector, including households and their individual members.

# Research History

Figure 1 illustrates how the research field of user innovation has evolved, using as a measure the number of publications listed as search results in Google Scholar with the search string “user innovations.” The “user innovation” phenomenon was first systematically described by Eric von Hippel in 1976. From then, as illustrated in Figure 1, he and many coauthors conducted empirical studies in which they documented the prevalence of innovating users (72 publication in the 1980s). This research work led to the seminal book *The*

*Sources of Innovation* (1988). In this first comprehensive documentation of user innovation research, von Hippel reported the first studies demonstrating the prevalence and technological significance of user-developed products in various technology-based industries. He explained variations in the sources of innovation and introduced the lead user method as a systematic framework for firms aiming to benefit from user innovativeness. Most likely stimulated partly by this summary, the body of research grew, but at a rather low rate during the 1990s (179 publications; see Figure 1). Clearly, the phenomenon was still interpreted as a somewhat exotic exception to the dominating paradigm, according to which innovation is overwhelmingly producer-driven.

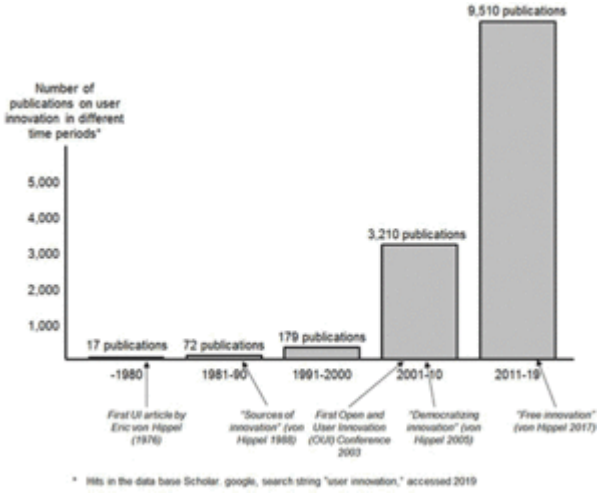


*Figure 1.* Development of the academic field "user innovation."

However, a growing research community contributed evidence of the existence of innovating users. While early user innovation studies focused on professional users and user firms, research in the 1990s and the first years of the new millennium repeatedly showed that users also innovate in the consumer goods sector (Lüthje, 2000, 2004; Shah, 2000). Focusing on end users and consumers, user innovation researchers increasingly turned their attention to factors that enable and motivate users to innovate. Their studies provided more fine-grained answers to the question of why users engage in innovation work, while helping to develop a better understanding of the boundary conditions for user innovations. Scholarly interest increased considerably in the new millennium, when the rise of the Internet, along with shrinking transaction and communication costs, prompted new phenomena such as virtual user communities and open source software projects (more than 3,000 publications between 2000 and 2010; see Figure 1,). Many scholars were drawn into the field and conducted investigations into open source software development projects (Lakhani & von Hippel, 2003), into networks of physicians (Lettl, Herstatt, & Gemuenden, 2006), and into consumer communities (Franke & Shah, 2003) in various recreational fields, particularly sports, gaming, and music. In addition, the question of how firms could "hunt," "harvest," and "farm" user innovations was broadly researched. Moreover, whereas the lead user method, proposed by Urban and von Hippel (1988), had for long been the only one used for this purpose, additional methods for deliberately

transferring innovation work to firms, such as toolkits (von Hippel, 2001), innovation communities, and contests (Afuah & Tucci, 2012; Jeppesen & Lakhani, 2010), were now proposed, described, and analyzed.

All this new evidence was incorporated into Eric von Hippel's second book, *Democratizing Innovation*, which appeared in 2005. Since then, the idea of distributed and open forms of innovation has gained even more attention. While the concepts of user innovation and open innovation are not identical, user innovation researchers have generated important advances in the use of (large) crowds as an innovation source. The formation of the Open and User Innovation Society (OUI) and the organization of a yearly international conference on open and user innovation have led to the development of a growing global research community. This is apparent in the large number of research publications since 2010 (more than 9,500 publications up to April 2019; see Figure 1).

Von Hippel's third book, *Free Innovation*, published in 2017, develops the idea of large crowds even further by highlighting the open, distributed, and self-driven nature of innovation work in today's world. It synthesizes the findings of research on innovation work performed by millions of people during their unpaid, discretionary time, the results of which were made available as a free good. These activities can be termed "free" innovation as the innovators primarily benefit by self-rewards involving no form of commercial transaction (e.g., selling on markets; von Hippel, 2017). As an imperative phrase ("free innovation!"), the book's title is also a request to policymakers to take action and support user innovation activities. The evidence reported in it highlights the trend toward fully democratized innovation practices that enable almost anybody to exploit her or his creative potential to pursue novel solutions that maximize both personal use value and social welfare.

# Why Users Innovate

The proverb "necessity is the mother of invention" highlights the key driver of user innovation activities. The vast majority of users who innovate do so to solve personal use problems or to obtain solutions that best fit their needs (de Jong, von Hippel, Gault, Kuusito, & Rausch, 2015; de Jong & von Hippel, 2013; Stock, Oliveira, & von Hippel, 2015; von Hippel, Ogawa, & de Jong, 2011; von Hippel de Jong, & Flowers, 2012). Many studies have documented examples indicating the high importance of use-related benefits. Those who play sport as a hobby develop new gear to have more fun playing sport (Franke & Shah, 2003; Hienerth, 2006; Lüthje, Herstatt, & von Hippel, 2005; Shah, 2000); surgeons develop new surgical instruments to perform better operations (Lettl et al., 2006; Lüthje, 2003); and manufacturing companies modify their machinery to reduce their in-house production costs (von Hippel, 1988). Even the development of the technologies behind the World Wide Web was primarily driven by Tim Berners-Lee's desire to benefit from using them in his work in order to improve information sharing between scientists working at his employer, CERN (McPherson, 2009).

It may be no surprise that most users innovate to gain use value as, by definition, users can benefit primarily from the use of technologies, products, and services. However, one might wonder why users attempt to innovate rather than buying products and services already on the market that meet their requirements, since producers should, after all, have a strong economic incentive to design products that fulfill users' needs. One key reason why users do not rely on this strategy is that their needs are extremely heterogeneous (e.g., Franke, Reisinger, & Hoppe, 2009). In many markets, consumers want a wide range of different things, so for producer firms it is often not economically viable to offer a tailor-made solution to each individual customer. In order to keep costs at a moderate level, producers create a limited number of standard variants, each tailored to the average needs of a particular consumer segment. Admittedly, the costs of individualization have been considerably reduced by the concept of mass customization, by advances in additive manufacturing, and by the rapid developments in digital technologies. Yet, even so, in many markets the strategy of mass production and segmentation has remained more profitable (Franke & Hader, 2014). Consequently, in markets with heterogeneous needs, many users remain dissatisfied with existing market offers and are thus forced to engage in innovation themselves in order to solve their particular use problems.

Another important reason why existing commercial products may fail to meet user requirements is the difficulty of transferring information about needs and preferences from users to producers. The "stickiness" of a given unit of information is defined as the incremental expenditure required to transfer it from its origin to another locus (von Hippel, 1998) and may result from attributes of the information itself (von Hippel, 1994). When user needs are sticky, the reason is often that they are deeply rooted in the personal experience of individuals and can hardly be encoded in explicit terms; that is, they constitute tacit knowledge (Polanyi, 1983). Users' needs are tacit, for example, when they relate to sensual perceptions since it is quite difficult for them to describe precisely their preferences regarding their ideal perfume, pop song, fashion item, mattress, or movie. Users also lack awareness of their needs regarding complex behavior. For instance, users of sports equipment may find it hard to explain what would make a given sport more fun (Shah, 2000). Or medical experts may lack full awareness of the mental processes they follow in trying to reach a valid diagnosis of a disease—information that would greatly assist medical companies in developing better diagnostic technology (von Hippel, 2005).

The sticky information problem is often aggravated by producers' low level of "absorptive capacity." This means that, even when users are willing and able to articulate use problems and unmet needs explicitly, this information does not necessarily reach producers. Moreover, many of these have not implemented communication channels to users. And if they have, they may lack the capability to distinguish valuable information from mere "noise" such as useless ideas, complaints, stupid questions, or nonsense (McCabe, 2010), or they may simply misunderstand users (Schweisfurth, 2017; von Hippel, 2005). Last but far from least, even if users have insight into their preferences and are able to articulate them, and even if a producer actually receives this information, can understand it, and is willing to develop a product adapted to those preferences—and that is a lot of "ifs"—the development process always takes time, whereas many users need a solution immediate-

ly. All this explains why users, rather than relying on producers to innovate, may choose to do so themselves.

The decision to go down that road is not prompted solely by the hope of benefiting from the use of an innovation. When asked about their motivations, users often indicate that they see their engagement as a self-rewarding experience generating personal enjoyment and offering multiple learning opportunities (e.g., Brabham, 2010; Füller, 2010; Lakhani & Wolf, 2005). Users innovate because they are interested in the task itself and because they hope to satisfy their intellectual interest or curiosity (e.g., Füller, Mühlbacher, Matzler, & Jawecki, 2009; Hsu, Ju, Yen, & Chang, 2007; Nambisan & Baron, 2009). In a similar vein, innovation work can fulfill an urge for self-determination (Ryan & Deci, 2000), offer the experience of flow (Csikszentmihalyi, 2000), and lead to products with a high subjective ownership and identification value (Franke, Poetz, & Schreier, 2013).

Users involved in user innovation communities report that they are motivated by gaining appreciation and allegiance in such a community (Benkler, 2006; Franke & Schreier, 2010). Having a high status within an innovation community can translate into economic benefits, such as rewards or relationships with potential employers (Ebner, Leimeister, & Krcmar, 2009; Füller, 2006, 2010; Jeppesen & Frederiksen, 2006; Leimeister, Huber, Bretschneider, & Krcmar, 2009). A good reputation in an innovation community can also lead to higher levels of satisfaction with the innovation task or strengthen feelings of self-esteem (e.g., Wu & Sukoco, 2010). Empirical studies on user behavior in innovation communities have revealed that altruism (i.e., the desire to help others) also prompts users to engage in innovation (Harhoff, Henkel, & von Hippel, 2003; Hars & Ou, 2002; Lakhani & von Hippel, 2003).

For many users who are driven by such self-rewards, financial compensations play no role (free innovation; von Hippel, 2017). However, some user innovators see the value their achievements may provide to others and are at least partly motivated by the prospect of making money. Some license their technologies and sell their innovations to commercial producers (Baldwin, Hienerth, & von Hippel, 2006; Block, Henkel, Schweisfurth, & Stiegler, 2016). Others decide to exploit the entrepreneurial opportunities by starting their own business and becoming “user entrepreneurs” (Haefliger, Jäger, & von Krogh, 2010; Shah & Tripsas, 2007). Thus, expectations of monetary benefit, too, stimulate users to innovate.

The broad spectrum of motives also contributes to our understanding of *who* innovates. Only those users whose benefit expectations outweigh their innovation-related costs are likely to show enduring commitment to innovation (e.g., Deci & Ryan, 2000; Schmookler, 1966). However, while high motivation is a necessary condition for starting innovation endeavors, it may not be sufficient to explain why such efforts are successful. Not all user innovation activities result in attractive solutions having the potential to be used by other users or to become the basis of a commercial market offer. Research has shown that high-potential innovation work is concentrated among “lead users.” This concept was introduced by von Hippel (1986) to capture the essence of those users most likely to come up

with valuable new products and services. Lead users have two key characteristics. The first is a particularly high expectation of benefit from the innovation. Because they urgently need a novel solution, such users invest in innovating (von Hippel, 1986, 2005). Their second characteristic is their leading-edge status. Lead users are ahead of the market in important need-related trends, so what they want today is what most users in that market will be demanding in the future. This second feature accordingly affects the commercial attractiveness of the innovations developed. It also qualifies lead users to be used as a need-forecasting laboratory (von Hippel, 1986). It is important to note that lead user status is a continuous variable (Morrison, Roberts, & Midgley, 2004). Any demarcation between lead users and non–lead users is necessarily somewhat arbitrary. In addition, whether a user will benefit from an innovation, or is ahead of the trend, is contingent on the specific product or service category for which lead users are to be identified. A given user may have a high lead user status with regard to product category A but a low one with regard to product field B. Thus, lead users are not a distinct "species."

Finally, research has found that, as well as increasing the likelihood of attractive innovations, lead user status is correlated with other characteristics such as creativity, adoption behavior, or opinion leadership (Faullant, Schwatz, Krajger, & Breitenecker, 2012; Schreier & Prügl, 2008) This suggests that lead users constitute a valuable information source in all phases of producers' innovation processes. They can be integrated into market forecasting, idea and concept testing, product design, and the diffusion of innovations (e.g., Ozer, 2009).

# How Users Innovate

User needs are often urgent. Furthermore, users usually command very limited resources, particularly in B2C settings. These factors force them to operate in low-cost corridors of innovation and determine how they typically innovate (Lüthje & Stockstrom, 2016; von Hippel, 2005).

Generally, users tend to focus on local knowledge, that is, on resources they already have (Lüthje et al., 2005). To reduce their costs, they draw on their existing knowledge, striving to creatively exploit their distinctive capabilities and assets rather than investing in the acquisition, combination, and exploitation of new resources. This is most obvious with regard to information about user needs. As explained above, users often innovate because they expect to benefit from using their innovations. In such cases, it is rational for them to ignore general marketplace needs, so they need not invest, as producers do, in collecting information about emergent and future customer needs (Franke & Shah, 2003; Hienerth, von Hippel, & Jensen, 2014; Morrison, Roberts, & von Hippel, 2000).

In the process of solution development, users also have a strong inclination to employ their existing tangible assets and to (re-)use existing knowledge. As identifying, matching, and applying new solution-related knowledge from external sources is often costly, users search for solutions close to the competences and knowledge they already possess (Rosenkopf & Nerkar, 2001; Shah, 2000; Slaughter, 1993). For instance, Lüthje et al.

(2005) found that only 15.6% of a sample of innovating mountain bikers acquired any new knowledge in order to develop their inventions. Most of them relied completely on knowledge they already possessed from their job or from other hobbies. Nevertheless, applying existing stocks of solution-related knowledge does not necessarily imply that users are restricted to a limited search in the close environment of the focal inventive problem. Very often, users transfer knowledge from hobbies, former jobs, and fields of private interest and apply general-purpose items to solve the problem. As a result, user innovations may often be rather pragmatic (“rough and ready”). However, they can also provide more original solutions than perfectly polished producer innovations.

When scanning for complementary resources, user innovators frequently draw on communities of like-minded peers (Franke & Shah, 2003). By doing so, they gain access to large pools of knowledge, skills, assistance, and feedback from a broad range of domains. Such sources have been enriched by virtual user networks and online user communities (Baldwin et al., 2006; Jeppesen & Frederiksen, 2006). While the reasons for the increasing popularity of user communities are manifold, the reduction of problem-solving costs is one key reason why innovating users often organize into such (online) groups.

The strong incentive to keep innovation costs low not only determines the type of resources that users use in the process, it also influences the innovation process itself. Users tend to follow problem-solving processes characterized by iterative trial-and-error and fast experimentation. Trial-and-error problem solving consists of fast cycles that start with the development of preliminary solutions, continue with a test of those prototypes, and conclude with an analysis of the test results. The insights derived from that analysis are then used as the input for the next development and test cycle (von Hippel, 2005). Users are well placed to engage in fast experimentation and to arrive at valid test results, simply because they have direct access to test environments. Very often, their test-beds are precisely those everyday use environments in which they carry out their activities. Users therefore have “a low-cost laboratory for testing and comparing different solutions” (von Hippel, 2005, p. 75). In extreme cases, they themselves are the lab, in that they can test an innovative concept on themselves without the need for any further test environment at all. For instance, a hobby mountain biker can experiment with self-developed pedals designed to improve force transmission in the course of their everyday riding activities—at no additional cost.

# What Happens to User Innovations

Several examples highlight how some user innovations can induce fundamental changes in market dynamics and pave the way for the creation of totally new markets (Hienerth, 2006). One is the World Wide Web, which has been central to the information age since it connects billions of Internet users and provides them with easy access to an infinite pool of information. Another is the free operating system kernel Linux, developed by Linus Torvalds because he needed a solution for his own work (he programmed a terminal emulator to access the UNIX-server of his university). Today, Linux is installed in millions of

desktop computers and servers and is used in many electronic devices (Henkel, 2006). Millions of people now use planes, ball pens, dishwashers, and Wikipedia and engage in sports, cultural activities, and hobbies that can be traced back to the ideas and pioneering work of other users. These and many more examples illustrate how user innovations impact our well-being.

A key reason why many user innovations have been so successful in terms of diffusion and usage is the strong inclination of innovating users to freely reveal the results of their work. Empirical research shows that many voluntarily give up their intellectual property rights by publishing proprietary design information and allowing others to use or to modify their designs free of charge (Harhoff et al., 2003). This behavior has been documented by von Hippel and Finkelstein (1979) for medical equipment, by Lim (2000) for semiconductor process equipment, by Morrison et al. (2000) for library information systems, and by Franke and Shah (2003) for sports equipment. In open-source software projects, the General Public License (GPL) system requires free revealing of new software code, thus making it the norm (Stallman, 1999). Research clearly shows that the vast majority of private innovators are also willing to freely reveal their inventions to everyone (de Jong et al., 2015; von Hippel, 2017).

The fact that users give valuable innovations away without requiring any payment is, at first sight, counterintuitive. However, many users simply have no reason to protect or hide their innovations. They do not risk losing anything by freely revealing as they do not compete with other users and, in any case, do not strive for commercialization (Jeppesen & Frederiksen, 2006). For example, a hobby craftsman who develops an effective low-cost insulation solution for his own house has no reason not to allow other house owners to benefit from his invention. Building a business on such an innovation is difficult, and it is in any case virtually impossible to prevent imitation. But many users not only accept imitation, they actively seek to publish proprietary information about their innovation designs. They do so because they expect to obtain private benefits from free revealing (von Hippel & von Krogh, 2003). Some of these benefit expectations overlap with the motivations for user innovation. Most notably, free revealing helps to improve a user’s reputation as a capable innovator, while reputational gains can, in turn, increase profits for an innovating user firm (Allen, 1983) as well as the career prospects or salaries of individual innovators (Lerner & Tirole, 2002). In some cases, users hope that an innovation is adopted by a firm that can sell it at a price below the costs to them of building the innovation themselves (Harhoff, Henkel, & von Hippel, 2003). Similarly, publishing an innovation can invite other users to improve, debug, or further develop it to the benefit of everyone, including the original innovator (von Hippel & von Krogh, 2003). If an innovation is developed within a user community, social norms will often impell the design to be made accessible to all community members. Such norms can prove very powerful, even in the absence of free public or open-source licenses, for reasons that are both psychological (identification and feelings of belonging to the community; Hertel, Niedner, & Herrmann, 2003) and economic (the community can sanction norm violators; Bauer, Franke, & Tuertscher, 2016; Fauchart & von Hippel, 2008). Consequently, most communities are characterized by open sharing of innovations among members, who sometimes even draw

up instructions intended to help other users follow and adopt their designs (e.g., Github, Instructables, or the Lego AFOL community; see Antorini & Muñiz, 2013; von Krogh, Spaeth, & Lakhani, 2003).

Despite the numerous examples of widely adopted and actively diffused user innovations, most useful user innovations are not actually disseminated (de Jong, von Hippel, Gault, Kuusisto, & Raasch, 2015; von Hippel et al., 2011, 2012). This "diffusion shortfall" (von Hippel, 2017; von Hippel, DeMonaco, & de Jong, 2017) seems to run counter to the high willingness of users to freely reveal their innovations. However, accepting imitation does not necessarily mean investing time and effort in making the public aware of an innovation and in helping supporting other users to copy and apply them. In fact, only rarely do user innovators without commercial objectives undertake significant efforts to diffuse their innovations (de Jong, Gillert, & Stock, 2018; von Hippel, 2017). Consumers primarily interested in self-rewards do not have strong incentives to invest in diffusion. For them. the possible benefits to other users are an externality that brings no payoff (de Jong et al., 2015). Moreover, it is costly for user-innovators to popularize their achievements since they lack both direct marketing links and access to broader communication channels (von Hippel et al., 2017).

It is possible for users to change their functional role and become producers (user entrepreneurship). However, although research documented a number of cases (Shah & Tripsas, 2007), it appears the exception rather than the rule for user innovators as it involves high opportunity costs. As lack of diffusion has been found to be weakly related to the general value that user innovations would have for others were they diffused, low levels of diffusion can be interpreted as a "market failure" (de Jong et al., 2015; von Hippel, 2017; von Hippel et al., 2017).

Theoretically, producer firms could constitute the missing link between users and markets since they have a clear incentive to invest in diffusion. Yet, while several empirical studies show that adopting user innovations can be highly beneficial for producers (e.g., Chatterji & Fabrizio, 2014; Lilien, Morrison, Searls, Sonnack, & von Hippel, 2002; Winston Smith & Shah, 2013), it has often been reported that the transfer of designs from users to producers is systematically neglected (von Hippel, 2017). One reason is that decision-makers underestimate the value of users as sources of innovation (Bradonjic, Franke, & Lüthje, 2019). Due to the diffusion shortfall, their innovations become popular only when commercialized by a producer. And producers, in launching a product on the market, have more incentive to portray themselves as the innovator than to reveal the true source. Consequently, the information that many innovations, in fact, come from users is systematically suppressed. In addition, transfer media such as academic textbooks, popular innovation books, and press articles barely report on user innovation. A recent analysis shows that users were mentioned as originators in only 2.7% of 3,469 paragraphs on the sources of innovations (Bradonjic, Franke, & Lüthje, 2019). This perceptual bias is often aggravated by the negative attitudes of decision-makers in producer firms toward externally generated innovative ideas. The "not-invented-here" syndrome (Antons, Declerck, Diener, Koch & Piller, 2017; Katz & Allen, 1982) even prompts many

producer firms to “close“ their products, precluding users from “hacking,” adapting, or changing their products (Braun & Herstatt, 2008).

# Methods for Identifying Attractive User Innovations

Producers are well advised to respond proactively to the ongoing paradigm change discussed above by complementing the traditional approach of producer-centered innovation with user-driven approaches. In the following, three different ways in which firms can benefit from user innovativeness are illustrated (Figure 2). They are, of course, not mutually exclusive and can therefore be used in combination. As the field of user innovation is quite dynamic, and many firms experiment with methods, the list is also not exhaustive.

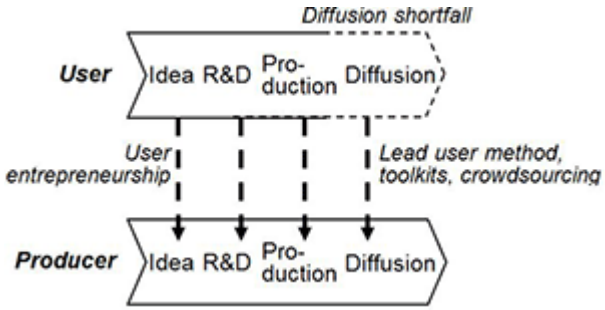


*Figure 2.* The diffusion of user innovations.

## The Lead User Method: The “Hunting” Approach

The lead user method was first proposed by Urban and von Hippel (1988). It is a managerial heuristic that enables companies to search for particularly attractive user innovations and identify radically new business opportunities (Figure 3). Usually, this method is described as comprising four phases (e.g., Lüthje & Herstatt, 2004).

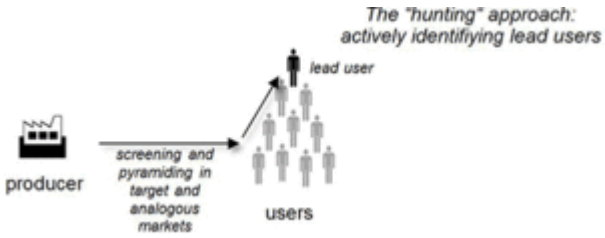


*Figure 3.* The lead user method.

In the initial phase, objectives are defined (e.g., “to find an innovative solution to problem X” or “to identify an innovative product concept in market Y”) and a cross-functional team is set up. The project team should include employees from different functions, such as R&D, marketing, or production, to ensure that the solutions found match with the firms strategic objectives, development capabilities, and production resources. Broad anchor-

age of the project within the organization also reduces the risk of “not-invented-here” problems arising from the fact that solutions external to the company are being sought.

In the second phase, the most important trends likely to impact the focal market or target industry are identified. This trend identification is necessary to narrow the problem down and to allow a systematic search for lead users in the next phase. Trends may reflect technological developments (e.g., a trend toward modularization or new materials) and/or be related to factors impacting the market (e.g., increasing demand for lightweight components). The most relevant trends are generally selected on the basis of interviews with experts, patent searches, information from online forums, and literature research (Moehrle, Pfennig, & Gerken, 2017).

The third phase involves a broad search for end users (B2C) or user firms (B2B) that are far ahead of the mass market with respect to the trends previously identified. This search aims at identifying users that are either strongly affected by a trend (e.g., those already displaying a need that many users will have in the future) or that lead a given trend (e.g., those having the highest level of expertise in a new emerging technology). Naturally, selected users must also be open, creative, willing to work in a team jointly with other lead users, possess sufficient verbal skills, etc. (Hoffman, Kopalle, & Novak, 2010). Most early lead user studies employed a mass screening approach in which a large sample of users (typically drawn from customer databases) was systematically filtered in order to identify those with high leading-edge status. More recently, such studies have increasingly turned to the pyramiding method to identify lead users (Lilien, Morrison, Searls, Sonnack, & von Hippel, 2002). In a pyramiding search, researchers start with a few users and ask them to identify trend-leading users with especially strong needs in their market. Those individuals are then contacted and asked the same questions, and the process continues until a sufficient level of “lead userness” is achieved (usually after two or three search search steps). Recently, experiments have demonstrated the superior efficiency of the pyramiding search strategy relative to screening (Stockstrom, Goduscheit, Lüthje, & Jørgensen, 2016; von Hippel, Franke, & Prügl, 2009).

Another advantage of pyramiding is the opportunity it provides to identify individuals outside a predefined population or sample (Poetz & Prügl, 2010). Analogous markets—that is, markets different from the target market but characterized by the same trends—are particularly valuable sources in the search for lead users (Franke et al., 2013). Consider the example of a lead user study that aims to find methods of preventing infections in clinical surgery. In this case, one important trend would be “increasing use of machines and medical equipment located close to patients,” which poses new challenges in terms of infection prevention in the operation room. In identifying responses to this challenge, experts from the analogous field of chip production may be able to provide valuable creative input. In general, there are two reasons why it can make sense to ask experts in analogous fields. On the one hand, they may possess solution-related knowledge that is worth transferring to the focal problem. On the other, they are less likely to be cognitively “locked” by existing solutions in the target field. Researchers have designed and tested combinations of several methods in lead user projects (“mountaineering”; Hyysalo et al.,

2015). Recent research has proposed machine learning and artificial intelligence as potential means of searching for lead users (Kratzer, Lettl, Franke, & Gloor, 2016) and for lead user innovations (Kaulartz & von Hippel, 2018).

In the fourth phase of the method, the lead users identified are invited to a two- or three-day workshop, in which company members from different functional areas should also participate (Lüthje & Herstatt, 2004). In these workshops, techniques such as brainstorming and group discussions are used to capitalize on participants' creativity. It is important for the company to address the issue of intellectual property rights prior to the workshop and to ensure that the ideas and concepts generated can be commercialized without the risk of breaking the law.

The most rigorous test of the lead user method was conducted by Lilien et al. (2002). In a field experiment, these authors studied the performance of 47 real, new-product development projects at 3M. They found that lead user projects had projected average sales of $146 million. The figure for projects that used other traditional, and primarily internal, ideation methods was $18 million—eight times less than the revenue potential of the lead user inventions.

## Toolkits for User Innovation and Design: The "Farming" Approach

In the lead user method, the development process is completed by a limited group of highly motivated and qualified users as problem solvers. Another way to build on users' creativity is to outsource individual product design to many—or even all—customers. If many customers are both creative and dissatisfied with standard offerings, why not provide them with tools to decrease their design costs? In other words: Why not shift design work to those who know best what they need? Toolkits for user innovation and design are sets of design tools that allow individual users to self-design their own individual products in line with their own preferences and to give visual and feedback information on (virtual) interim solutions (von Hippel, 1998, 2001; von Hippel & Katz, 2002) (Figure 4). If a customer likes what they have designed, they can order "their" product, and the toolkit provider will produce it according to their design specifications. Many companies have started offering toolkits that enable users to create online their own individual computer chips, machines, flavors, custom food, software, plastic polymers, industrial refrigerators, security systems, air conditioning systems, windows, electronic equipment, T-shirts, watches, breakfast cereals, cars, kitchens, sofas, skis, jewelry, laptops, pens, sneakers, and many other products. These can then be produced to order by a manufacturer.


*Figure 4*. Toolkits for user innovation.

Toolkits share two common features. First, they all contain design tools, in some form, that enable the user to create and modify a design. Some are quite restricted, consisting of lists to from which users can choose. Others are of the drag-and-drop variety; for example, users may be able to choose graphic symbols, place them virtually on skis, define the size of the symbol, and shift them around in order to find the position where their individual skis look best. There are also toolkits that allow users to combine product components in a modular fashion, like Lego bricks. Still others allow free design, for instance using a graphic computer program. Toolkits comprise functional aspects of the product (e.g., its material, size, shape, or features), the product's aesthetics (such as color, graphics, or styles) and the possibility of personalization (e.g., by adding one's name or logo). Toolkits can, of course, be applied in service industries, too. Some websites allow individual users to customize events such as wedding celebrations or short holidays, as well as electronic newspapers, financial investments and insurance policies, music, ring tones, mobile phone contracts, and so on. Toolkits are frequently incorporated into computer games, allowing the user to extend, modify, and create new game characters, maps, and surroundings (e.g., Boudreau & Jeppesen, 2014). The software industry is particularly suited to the use of toolkits as design and product often go together. A modification designed by means of a software programming toolkit does not need to be produced by a software company—it is ready immediately for other gamers to use.

A second characteristic that toolkits have in common is the feedback feature. In order to enable fast design iterations, toolkits provide information about intermediate designs. In consumer goods settings, the most common form of feedback is a virtual, simulated, visual representation of the current design that is updated in real time with every design change that users make. If the toolkit allows for functional product manipulation, feedback should also be functional. For example, a garden design toolkit may give an alarm in the event of functional trade-offs between users' design decisions (e.g., when a user positions a pond too close to a broadleaf tree so that its shade may stop aquatic plants from growing). Other toolkits inform users about price, weight, size, or other relevant technical performance parameters. In sum, a good toolkit provides the user with information about the probable consequences of design decisions, just as a capable salesperson would do in a sales meeting. This enables the user to engage in trial-and-error learning, which has been found to be very beneficial in the design of new solutions (von Hippel, 1998, 2007). Few of us have the imagination to come up with a precise, detailed, and definitive product specification on the spot. Most users cannot design a product purely in their mind; they need to play around, try different things, and find out iteratively what is best

for them. Toolkits should therefore be understood and built as “learning instruments” that support this approach to problem-solving (Franke & Hader, 2014).

Consumers can derive considerable value from using toolkits. Franke and Piller (2004) found that consumers’ willingness to pay (WTP) is twice as high for a self-designed watch as for the bestselling standard watches of the same objective quality. This dramatic value increase has been confirmed in several studies in the product areas of breakfast cereals, carving skis, mobile phone covers, fountain pens, kitchens, newspapers, scarves, and T-shirts (Franke, Keinz, & Steger, 2009, Franke, Schreier, & Kaiser, 2010; Franke & Schreier, 2008; Schreier, 2006). A number of factors have been identified as causing this value increment. First of all, customized products fit consumers’ preferences better (Dellaert & Stremersch, 2005; Franke, Keinz, & Steger, 2009), and they are perceived as more unique (Franke & Schreier, 2008). In addition, self-designed solutions provide the consumer with a sense of accomplishment (“I designed it myself”; Franke et al., 2010). Moreover, enjoyment of the design process as such augments the value that users derive from self-designing a product (Franke & Schreier, 2010). However, it is important to bear in mind that these sources of value depend on the design of the toolkit and need time to evolve. Typically, users’ affective state (and thus also willingness to complete the process) follows a U-shaped curve. Initially, motivation is high, but it falls as users discover that handling the toolkit and finding out which they one want are more difficult than anticipated. However, if they overcome this frustration and carry on, users experience even more positive emotions than at the beginning of the process (Krause, Franke, & Moreau, 2019).

Most existing studies on user innovation toolkits were conducted in the area of low-price consumer goods. The existing body of knowledge regarding the use of toolkits in industrial goods settings is quite limited. Nonetheless, externalizing product design to customers constitutes a major trend in these markets.

## Crowdsourcing: The “Harvesting” Approach

A third way to profit from user creativity is to “crowdsource“ the innovation task (Figure 5). The underlying idea is straightforward: a company makes a request for a solution or an innovation challenge in the form of an open call and rewards the best submissions from the “crowd” (Afuah & Tucci, 2012; Dahlander & Magnusson, 2008; Nambisan, 2002; Ogawa & Piller, 2006; Terwiesch & Xu, 2008).

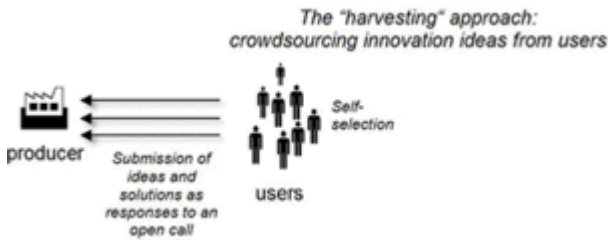


*Figure 5.* Crowdsourcing.

The value of crowdsourcing derives from two factors: first, the broad and unknown distribution of skill sets, perspectives on the problem, and solution heuristics (Jeppesen & Lakhani, 2010), and second, the self-selection of capable problem solvers (Franke, Reinsberger, & Topic, 2019). Raymond (1999) integrates these two factors into what he terms "Linus's law," namely "given enough eyeballs, all bugs are shallow." Consequently, crowdsourcing can result in surprisingly innovative solutions (Bullinger, Neyer, Rass, & Moeslein, 2010; Harhoff & Mayrhofer, 2010; Jeppesen & Lakhani, 2010; Nambisan & Baron, 2009, 2010; Poetz & Schreier, 2012; Terwiesch & Ulrich, 2009).

Many studies have helped us understand why users contribute to commercial, crowdsourcing business models, in which the firm benefits directly from contributor input. Partly, their motives overlap with those motivational drivers presented in the previous section as explanations of why users innovate in the first place and why they often decide to innovate in groups or communities of users (e.g., enjoyment of problem-solving, learning, reputation, altruism; Brabham, 2010; Füller, 2010; Füller, Matzler, & Hoppe, 2008, Füller et al., 2009; Nambisan & Baron, 2009). Social exchange theory (Blau, 1964) posits that voluntary exchange relationships are initiated and maintained when benefits exceed costs. The specific (additional) benefits that users may expect from participation in crowdsourcing include monetary rewards (e.g., Boudreau, Lacetera, & Lakhani, 2011; Brabham, 2010; Ebner et al., 2009; Füller, 2006, 2010; Hall & Graham, 2004; Leimeister et al., 2009; Nambisan & Baron, 2010), contacts with firms, and the appreciation of these (e.g., Ebner et al., 2009; Füller, 2006, 2010; Jeppesen & Frederiksen, 2006; Shah, 2006). Additionally, it has been found that potential participants not only calculate whether participation will pay off, they also form subjective evaluations of fairness in the crowdsourcing business model (Franke et al., 2013). They consider whether they get a "fair share," that is, whether benefits and costs are shared fairly with the organizing company (distributive fairness), whether they have a "voice" in decisions, and whether processes are consistent and transparent (procedural fairness). These fairness perceptions have clear behavioral consequences, as they inform individuals' propensity to submit a design to a crowdsourcing firm.

Research on crowdsourcing has provided several insights that can assist organizations in successfully designing the various phases of crowdsourcing processes (e.g., task definition, modes of broadcasting, attraction of problem solvers, evaluation and selection of inputs, rewarding the crowd). For example, firms using this approach should not overspecify the task even if they are searching for solutions to very specific scientific or technical problems since a high degree of specification places detrimental constraints on the crowd and may exclude valuable input of which the firms are not aware (Afuah & Tucci, 2012; Piezunka & Dahlander, 2015). After all, the most innovative solutions in crowdsourcing often result when a problem is abstracted from its context, which, in turn, elicits solutions from distant knowledge domains (e.g., Jeppesen & Lakhani, 2010). As regards incentives, monetary rewards have been found to be important, even if non-monetary motives are also present (Frey, Lüthje, & Haag, 2011). It seems that giving high rewards for a small number of winning concepts attracts more highly innovative contributions than a scheme that awards prizes to many contributors (e.g., Boudreau et al., 2011). For the evaluation

phase, studies have shown the critical importance of a transparent selection process (Piezunka & Dahlander, 2019). Empirical results also suggest that it may pay to involve the crowd in evaluating the inputs received (Poetz & Schreier, 2012). This ensures that problem solvers maintain long-term participation while supporting their perception of fairness, even if their ideas are rejected (Franke et al., 2013; Piezunka & Dahlander, 2019).

Of course, the three approaches presented (lead user method, user innovation toolkits, and crowdsourcing) overlap and can be combined in many ways. For example, it is possible to link a toolkit with a crowdsourcing approach (Piller & Walcher, 2006). In a way, this is what Apple did with the iPhone. It openly called for innovative applications and provided a specific software allowing a large crowd of external developers to create and to test their applications. This toolkit also ensures that any app programmed actually runs on a smartphone. In another combination, crowds may be used to develop the initial idea and to evaluate preliminary design solutions, while the intermediate design phase is implemented by a group of highly qualified toolkit users (Franke, Keinz, & Schreier, 2008; Jeppesen, 2005; Jeppesen & Frederiksen, 2006; Jeppesen & Molin, 2003). Finally, lead user search is often carried out using crowdsourcing search techniques, which involve the company posting open calls for solutions in expert communities (Hyysalo et al., 2015).

Developments in machine learning and artificial intelligence may also facilitate novel approaches, such as a direct and automatic identification of promising user innovations—without the detour of identifying lead users, developing toolkits, or organizing crowdsourcing contests. For example, Kaulartz and von Hippel (2018) describe how they identified the most important user innovations in kitesurfing by the traces they leave in the Internet.

# Policy Implications

Economic models clearly show that public welfare is enhanced by user innovation activities (Gambardella, Raasch, & von Hippel, 2017; Henkel & von Hippel, 2004), which can themselves be promoted by public policy in three ways. First, government authorities and public research agencies can fund and subsidize user innovation projects. Second, they can invest in infrastructure that supports user innovation, such as online platforms (Koch, Rapp & Kroeger, 2013) or makerspaces (Halbinger, 2018). For example, Svensson and Hartman (2018) show that investments in makerspaces in Swedish hospitals yield welfare returns of approximately 1,500%. Third, legislative bodies can ease legal restrictions on user innovation activities. These take various forms. For example, they can constrain users in accessing or re-using existing solutions, and patent law may make incorporating prior inventions into user-generated designs, and revealing these to other users, a highly risky undertaking (Torrance & von Hippel, 2016). Even well-meant regulations can inflict collateral damage on user innovation by increasing the cost to users of testing their inventions in a public space (e.g., testing new car prototypes on public roads or drones in the air; Torrance & von Hippel, 2015; von Hippel, 2017).

Supporting users in developing and testing innovations will be useful, but may not be enough. Measures to support the diffusion of user innovation may also be needed given the “diffusion shortfall“ outlined earlier. This market failure could be mitigated by introducing incentives for users to actively engage in diffusing their innovations through the provision of user innovators with low-cost channels to markets. Easier access to markets could enable users to sell their designs, sometimes even in direct competition with commercial firms. Fortunately, the Internet and the digitalization of many industries have made it increasingly feasible for users to access markets without pursuing the pathway of full-time entrepreneurs (Shah & Tripsas, 2007). They can offer their innovations in the numerous online (maker) marketspaces for digital products (e.g., photographs, computer games, software applications, 3D-designs, recipes) and for physical goods (e.g., electronic devices, gadgets, food and beverages, or gift products) that have emerged in the last few years (Weller et al., 2015; Whitson, Simon, & Parker, 2018; Wolf & McQuitty, 2013). Accessing these marketplaces is becoming increasingly easy (Galeotti & Moraga-González, 2009). In many open online markets, the commercialization of a new product is a matter of a few clicks. It seems plausible that, just as the availability of easy-to-use design and development tools has led to higher numbers of innovating users (Baldwin & von Hippel, 2011), the existence of low-cost links to markets can boost the number of commercially active users. This, in turn, may reduce the diffusion shortfall. However, there may be negative side effects if an increasing share of users sell their innovations on markets. Most obviously, commercial user activities may crowd out those involving free innovation (Hippel, 2017).

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