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Abstract

Today's innovation policies ignore that innovation is increasingly open, distributed and user-centered. The dominant logic in policymaking is one of producer-centered innovation. Commercial enterprises and public research organizations are supposed to be hampered by market failures (including problems with appropriation, uncertainty, indivisibility and asymmetric information) and accordingly need interventions like R&D tax credits, grant schemes, public research funding and support for collaboration in order to innovate more and better. In this paper we introduce the user-centered model as an alternative paradigm of how innovation 'works'. We discuss how it differs from traditional, linear producer-centered model, argue why it is legitimate to develop policies in support of it, and provide specific directions. In general, we conclude that user innovation policies are legitimate because they are marked by voluntary spillovers, but hampered by some specific system and market failures. Two general principles for policymaking are to not confuse user innovation with 'user-driven' innovation – which is producer-centered innovation in disguise – and to accept that except for organizations, individuals should be eligible for policy interventions too. After adopting these giant leaps, specific directions for policymaking include to 1. Stimulate networking and collaboration between users, 2. Facilitate the adoption of user innovations by producers, 3. Facilitate modular designs of innovations, 4. Improve individuals' technical skills, 5. Rethink intellectual property rights, 6. Explore a next generation of financial incentives and 7. Improve the measurement of user innovation in official statistics.

Keywords

User innovation, innovation policy, spillovers, market failure, system failure.

1. Introduction

Today, around the world innovation policies are offered to support organizations in their innovation-related efforts. Prominent examples include subsidies for research and development expenditures of private firms, and intellectual property law protections to increase the profits of those who introduce innovations into the marketplace. A recent inventory of policies in OECD countries demonstrated that all developed countries engage in innovation policy development, and moreover, that the scope of innovation policy is still increasing. In 2008, governments of the EU Member States offered no less than 1157 policy measures (Tsipouri et al., 2008). The main justification for these efforts is that the social return on innovation exceeds the private benefits of its direct beneficiaries. This is because of spillovers, implying that knowledge developed by one actor eventually becomes available to others, that technologies developed in separate contexts can be complementary, and that price-quality ratios for customers become better (Griliches, 1992; Jaffe, 1996). The existence of spillovers includes that other actors also benefit from enterprises' innovative efforts, and that more innovation results in a better economic performance and increased social welfare.

Policymakers' incumbent view of how innovations come to life is based on a producer-centered model. It is assumed that economically important innovations are developed by producers, and that these producers need to be able to protect their innovations by intellectual property rights in order to secure monopolies over them for some period of time (Arrow, 1962). The common thought is that actors innovate to gain direct economic advantage because of increased sales, customer retention, decreased costs or better quality as a consequence of product and/or process innovation. For example, the INNO-Policy TrendChart which lists the main innovation policy instruments offered in developed countries, defines innovation policy measures as those interventions 'where the target group (final beneficiaries) or organization eligible for funding or support are enterprises' (Tsipouri et al., 2008: p.13). In this vein, the linear model of innovation, despite being criticized extensively in the academic world, is still alive and kicking today (Godin, 2006).

An emerging and growing line of research shows that the producer-centered innovation model is often not correct. Evidence has been rapidly growing that users, rather than producers, frequently create and modify products to serve their own needs. Users can be either firms or individual end consumers that expect to benefit from *using* an innovative product. In contrast, producers expect to benefit from *selling* an innovative product (von Hippel, 2005). A firm or an individual can have different relationships to different innovations. For example, Boeing is a producer of airplanes, but it is also a user of machine tools. If one were examining innovations developed by Boeing for the airplanes it sells, Boeing would be a producer-innovator in those cases. But if one were considering innovations in metal-forming machinery developed by Boeing for in-house use in building airplanes, those would be categorized as user innovations and Boeing would be a user-innovator in those cases. Empirical studies have found that many of the successful products put on the market by producers were actually first developed by users – for example, in scientific instruments, sports equipment, ICT and medical applications. In addition, innovating users have been shown to often not take advantage of available intellectual property protections or innovation subsidies. They often revealed what they have developed to each other and to producers without charge (von Hippel, 2005).

From the perspective of the producer-centered model, innovation by users may leave policymakers with feelings of discomfort. A very prominent example is the many open-source software projects found today. Open-source software is developed by communities of volunteers who coordinate their activities through the Internet. Such projects induce very powerful innovations with great social benefits, but for policymakers it is uncertain if and how such innovations need to be supported. Although open-source projects show that user innovation can be as (or even more) effective than software innovations by producers, such projects are certainly not eligible for the bulk of the current policy interventions.

This paper explores the policy implications of the user-centered model of innovation. We first contrast the user-centered model of innovation with the traditional, producer-oriented view of how innovation happens. In section 2 we discuss both models of innovation. Their differences will be elaborated on, and empirical evidence will be discussed to show that user innovation is a widespread among firms and individual end consumers. Next, section 3 explains the legitimacy of policies for user innovation. It is shown that innovation by users is marked by significant spillovers which enhance social welfare, but user innovation is also hampered by specific market and system failures, preventing the model to grow to its full potential. Section 4 then elaborates on the consequences of user innovation for policy. Two general principles for policymaking are discussed first. The user-centered model should not be confused with 'user-driven' innovation (which is nothing more than a specific form of producer-centered innovation). Another principle is that access to policy interventions should also be open to individuals, not just organizations. Next, we provide some directions to achieve more neutral innovation policies including to 1. Stimulate networking and collaboration between users, 2. Facilitate the adoption of user innovations by producers, 3. Facilitate modular designs of innovations, 4. Improve individuals' technical skills, 5. Rethink intellectual property rights, 6. Introduce a next generation of financial incentives and 7. Improve the measurement of innovation in official statistics. Section 5 then further discusses our ideas and proposes an agenda for future research. We conclude that social welfare will benefit from a policy mix which is less biased towards the producer-oriented model, and that policies to account for the emerging user-centered model are merited.

2. An alternative paradigm

This section first describes the producer-oriented, linear model of innovation. Next, we discuss what user innovation is about and how it differs from producer-oriented innovation. The section proceeds with an overview of empirical evidence to denote that user innovation is not an incidental phenomenon, and ends with an overview of the user-centered model that is marked by openness and distribution of innovative behavior across many individuals.

2.1 Producer-centered model

The dominant logic in today's policymaking is one of producer-centered innovation. It is assumed that most important innovations originate from producers and be supplied to consumers via goods that were for sale. This view stems from the traditional, linear model of innovation postulating that innovation starts with basic research. Results with commercial potential then move to applied research and to development of new products and processes. Production and diffusion then follow (Figure 1).

Figure 1. Producer-centered, linear model of innovation

First versions of the linear model were proposed at the beginning of the twentieth century, but broad application only took off with the emergence of the large multinational organizations who organized their innovation processes in large R&D departments (Godin, 2006). Since the fifties, the model was subsequently adopted by policy makers and statistical offices (OECD, 1962), and scientists in economics (e.g. Nelson, 1959) and management (e.g. Myers and Marquis, 1969). In fact, the linear model became an 'entrenched fact of life' since statistical indicators based on the linear model were developed and broadly adopted in the 1960s (e.g. NSF, 1953; OECD, 1962). The Frascati Manual (OECD, 2002), drawing heavily on the linear model, became a standard practice for conducting R&D surveys and for producing statistical indicators for policy targets, and for this reason, rival models could never easily become substitutes (Godin, 2006).

Public innovation policies drawing on the linear model basically argue that basic and applied research induce innovation and diffusion, which in turn results in productivity gains and economic growth. It is also argued that private investments in research will be too scant, because of knowledge spillovers and the ability of other economic agents to 'free ride' on innovation investments. Market failures, including insufficient opportunities to appropriate research output and the uncertainty and indivisibility of many innovations, bring about that private parties will under-invest in innovation (Nelson, 1959; Arrow, 1962). As a consequence, it is considered legitimate to offer policies to subsidize research and development and to offer intellectual property rights (Teece, 1986).

Scientists have extensively criticized the linear model, a process that actually started in the early years of its existence. There has been a demand-pull version of the model, arguing that innovation was driven by the perceived demand of potential users – research would develop products in efforts to respond to customer problems or suggestions (Rothwell, 1992). Other major concerns were the assumed linearity of innovation, i.e. relationships between science, development, production and diffusion have been proposed to be complex and interrelated (e.g. Price, 1965; Kline, 1985; Rothwell, 1992). It has also been suggested that successful innovators utilize multiple sources of innovation, including in-house R&D and linkages to customers, competitors and other network partners (Freeman, 1991). Besides, some have stressed the informal way of innovation. The linear model corresponds with a science, technology and innovation (STI) mode of innovation, and is based on the production and use of codified scientific and technological knowledge. Alternatively, there is a proposed doing, using and interacting (DUI) mode which relies on informal processes of learning and experience-based know-how (Jensen et al., 2007). Although such critics are widely shared, all proposed models regard producers as key actors in innovation, and accordingly today's innovation policies are still drawing heavily on the producer-centered, linear model. Policy interventions generally deal with firms' R&D expenditures, collaborations with universities, public investments in scientific research, and the valorization of basic knowledge.

The producer-centered model seems reasonable on the face of it – producers generally serve many users and so can profit from multiple copies of a single innovative design. Individual users in contrast, depend upon benefits from in-house use of an innovation to recoup any investment in innovation. Presumably, therefore, a producer who serves many customers can afford to invest more in innovation than any single user. From this it follows logically that producer-developed designs should dominate user-developed designs in most parts of the economy. However, we argue that in current policies an 'innovation gap' is present between the types of innovation that matter most to businesses and the established policy interventions that are intended to promote innovation.

2.2 User innovation

As mentioned in the introduction section, user innovators can either firms or individual consumers that expect to benefit from *using* an innovative product. In contrast, producer innovators expect to benefit from *selling* an innovative product. Firm or individuals can be both producer- or user innovators in specific situations. For example, Sony is a producer of electronic equipment, but it is also a user of machine tools. With respect to the innovations that it develops for its electronic products, it is a producer innovator, but if we would investigate innovations in its machinery or production processes, the company could qualify as a user innovator. Both types represent 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 'producers') must sell innovation-related products to users, indirectly or directly, in order to profit from innovations. Thus, in order to profit, producer inventors must sell or license knowledge related to innovations, and producer manufacturers must sell products or services incorporating innovations.

The distinction how producers and users benefit from innovation is the main and exclusive difference between both types. Some more distinguishing features are presented in Table 1 (derived from von Hippel, 2005). In advance, we remark that except for the top row these are not exclusive features of either producer or user innovation, but rather should be regarded as extremes on a continuum.

Table 1. Features of producer and user innovators

	Producer innovator	*User innovator*
Benefit from innovation	by selling	by using
Motive to innovate	opportunity	necessity
Type of actor	mainly organizations (enterprises, PROs, self-employed)	many individuals, also including end consumers
Type of knowledge	solution information	need information
Type of innovation	Improving quality, reliability, design	Bringing functional novelty
Phase in industry life cycle	Incumbent/mature phases	Nascent and emerging phases
Diffusion mechanisms	sales, licensing, involuntary spillovers	voluntary spillovers

User-innovators tend to be triggered by different motives than producers. They tend to innovate if they want something that is not available on the market, and are able and willing to invest in its development – necessity is what drives them. In practice, many users do not find precisely what they need on incumbent markets. Meta-analyses of market-segmentation studies suggest that user needs for products are highly heterogeneous in many fields (Franke & Reisinger, 2003). Producers tend to follow product development strategies to meet the needs of homogenous market segments. They are motivated by perceived opportunities to serve sufficiently large numbers of customers (users) to justify their innovation investments. This strategy of 'few sizes fit all' however leaves many users dissatisfied with commercial products on offer. As a consequence, some of them will modify their products or have a high willingness to spend time and money to develop a 'home built' version of a product that exactly satisfies their needs (von Hippel, 2005).

Producers and users tend to be different types of actors. Producers are typically organizations, including commercial enterprises, knowledge institutes such as universities and public research organizations, or self-employed inventors aiming to make money from their ideas. On the other hand, a user innovator may be any person facing a specific need that cannot be met by incumbent market offerings. The user model more dominantly recognizes individuals as potential innovators. They may very well be commercial firms developing equipment or processes for in house use, but also hobbyists such as contributors to open-source projects or end consumers in sports communities.

Users and producers tend to know different things and accordingly employ different knowledge in the innovation process. Users have the advantage of knowing precisely what they want, i.e. they possess superior need information. Producers need to rely on market research to get a glimpse of unsatisfied user needs, but in practice, this is difficult. Estimates of failed product innovations range from 75 to 90 percent of all new product introductions (Cooper, 2003). User innovators possess 'sticky information' about their needs - information that is costly to transfer from one individual to another because of differences in background knowledge, experience, and context of use information (von Hippel, 1994). Transferring this information to producers is expensive and tends to make user innovation more efficient than attempting to teach producers on user needs. A study of innovations in mountain biking equipment, for example, found that user innovations often depended on information that the inventors had obtained through their own cycling experience, reflecting their own unique circumstances and interests, such as a desire to bike in extreme weather conditions or to perform acrobatic stunts (von Hippel, 2005). Producers, on the other hand, possess better capabilities to design and market innovations, i.e. they employ specialized engineers, have professional software and machines, and an infrastructure to develop and market innovations for larger numbers of users. In sum, producers are advanced in terms of solution information, while users are advanced in terms of need information.

This distinct knowledge has direct implications for the types of innovations that producers and users develop. Due to information stickiness, innovators tend to rely on information they already have in stock (von Hippel, 1994). Users are more likely to come up with functionally novel innovations, requiring a great deal of user-need information and use-context information for their development. In contrast, producers tend to produce incremental innovations that are improvements on well-known needs and that require a rich understanding of solution information for their development, including design, reliability and technical quality. Their innovations tend to look more 'professional' and 'sustainable', while user innovations on average seem like amateur jobs but with superior new functionality. In this context, Riggs and von Hippel (1994) studied the types of innovations made by users and producers that improved the functioning of two major types of scientific instruments. They found that users are significantly more likely than producers to develop innovations that enabled the instruments to do qualitatively new things for the first time. In contrast, producers developed innovations that enabled users to do the same things they had been doing, but to do them more conveniently or reliably.

Another distinction is that user innovators are most significant in the early stages of industry emergence, while producers tend to enter only later when sufficient numbers of users can be identified with homogenous needs. User innovators tend to active in the nascent and emerging phases of the industry life cycle. Studies of innovating users (both individuals and firms) show them to have the characteristics of 'lead users'. That is, they are ahead of the majority of users in their populations with respect to an important market trend, and they expect to gain relatively high benefits from a solution to the needs they have encountered there. It has been demonstrated that many of the novel products developed by users for their own use are appealing to other users, and some of these provide the basis for products that commercial producers commercialize (Lilien et al., 2002). A typical pattern is that users initially only innovate for themselves – they may do this solo or in collaboration with other users (e.g. open-source projects). Next, user innovators may face requests from other users willing to adopt their products. They sometimes decide to start their own business to commercialize their innovations, and become producers on second thought (Shah & Tripsas, 2007). As this stage policy makers may recognize that a new industry emerges which may start to show up in official statistics. Incumbent producers typically enter at this stage. They may feel attracted by the opportunity of serving larger numbers of users with improved versions of user innovations.

A final, important distinction is that producer and user innovators differ in how they see their innovations diffuse to other actors. As indicated, producers expect to benefit from their innovations by selling them to users, or alternatively, by selling or licensing their innovative knowledge to other producers who might do the job of commercialization. Other actors may also benefit from producer innovations via spillovers, but producers consider these undesirable and at the expense of their hard work – so governments introduced intellectual property rights in order not to deprive producers from engaging in innovation. In contradiction, user often achieve widespread diffusion by just revealing what they have developed (Harhoff et al., 2003). This may seem strange, but it is often the best or the only practical option available to users, as hiding innovations with trade secrets is unlikely to be effective for long and user innovators do not care too much about direct economic benefits anyway[4].

[4] The case user innovators deciding to start a business to commercialize their innovations (e.g. Shah & Tripsas, 2007) is an exception to this rule of thumb,

2.3 Frequency of user innovation

Many of those who hear about user innovation for the first time regard it as a rare and insignificant phenomenon. In the past decade however, empirical evidence has shown that user innovation is widespread and growing in importance.

Qualitative observations have long indicated that producers have no monopoly on innovation. In his *Wealth of Nations*, Adam Smith (1776) pointed out the importance of 'the invention of a great number of machines which facilitate and abridge labor, and enable one man to do the work of many'. He went on to note that 'a great part of the machines made use of in those manufactures in which labor is most subdivided, were originally the invention of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it'.

Early empirical user innovation studies were concerned with specific product types. Von Hippel (1976) identified a high ratio of user to producer innovation in a sample of the most important innovations in scientific instruments in the past 20-30 years. Other examples include medical equipment (von Hippel and Finkelstein, 1979) and sports equipment (Shah, 2000). Alternatively, researchers have identified the proportion of user populations engaging in innovation affecting specific product categories. These types of study begin by identifying a population of users that are interested in a specific type of product, then each firm or individual in the sample is asked whether it has developed an innovation in the field at issue in order to use it. These studies generally find that 10 to 40 percent of user populations are innovators (von Hippel, 2005). The phenomenon has been identified as substantial in printed circuit CAD software (Urban & von Hippel, 1988), pipe hanger hardware (Herstatt & von Hippel, 1992), library information systems (Morrison et al., 2000), surgical equipment (Lüthje, 2003), Apache OS server software security features (Franke & von Hippel, 2003), outdoor consumer products (Lüthje, 2004), extreme sporting equipment (Franke & Shah, 2003), mountain biking equipment (Lüthje et al., 2002) and banking services (Oliveira & von Hippel, 2009).

Until recently, empirical evidence could be not considered representative for larger populations. Recent work however shows that user innovation is very common in broad samples of firms, and, even more striking, that also substantial numbers of end consumers are user innovators. See Table 2.

Table 2. Frequency of user innovators in broad samples of firms and end consumers

Source	*Country*	*Year*	*Sample*	*Frequency*
Arundel & Sonntag (1999)	Canada	1998	4200 manufacturing plants with > 20 employees and $ 250K revenues	48%
Schaan & Uhrbach (2009)	Canada	2007	6478 manufacturing plants with > 20 employees and $ 250K revenues	43%
de Jong & von Hippel (2009)	Netherlands	2007	498 high-tech small firms (1-100 employees)	54%
de Jong & von Hippel (2008)	Netherlands	2008	2416 small firms (1-100 employees)	21%
Flowers et al. (2009)	United Kingdom	2009	1004 small- and medium-sized firms (10-250 employees)	15%
Flowers et al. (2009)	United Kingdom	2009	2106 individual end consumers > 15 of age	8%

So far, three countries have been at the leading edge of surveying user innovation. An early study identifying user innovation in a broad sample was written up by Arundel and Sonntag (1999). As part of their survey of Advanced Manufacturing Technologies, Statistics Canada sampled thousands of Canadian manufacturing plants with at least 20 employees and $ 250 000 revenues. Amongst other questions, data were collected on the adoption, modification and development of specific technologies. A key finding was that 48 percent of the surveyed plants either modified existing technologies, or developed their own technologies to apply in their operations. More recently, this survey was updated by Schaan and Uhrbach (2009). They found that 43 percent of the surveyed manufacturing plants were user innovators.

In the Netherlands, researchers have examined user innovation in small firms, i.e. with 1 to 100 employees. These studies sampled individual small business owners to ask if they had developed innovations for internal use. In a sample of 498 high-tech firms, de Jong and von Hippel (2009) found that 54% had somehow engaged in user innovation in the past three years. Another sample focused on small firms in all (for profit) industries, and found that 21% of the small firm population is a user innovator (de Jong and von Hippel, 2008).

In the United Kingdom, this finding has recently been reproduced for a sample of firms with 10 to 250 employees from all industries. Here, it was estimated that 15% of the UK business population is a user innovator (Flowers et al., 2009). Moreover, in this study a first attempt was done to map user innovation by individual end consumers. Since it has generally been assumed that 'consumers just consume' products and services, incumbent statistical indicators do not capture innovation by consumers at all. Findings from an omnibus survey of 2109 individuals, after conservative adjustment for false positives, show that in the past three years 8% of the UK consumers (aged > 15) created or modified one or more of the consumer products they used, in order to make something better suited to their needs than products available on the market.

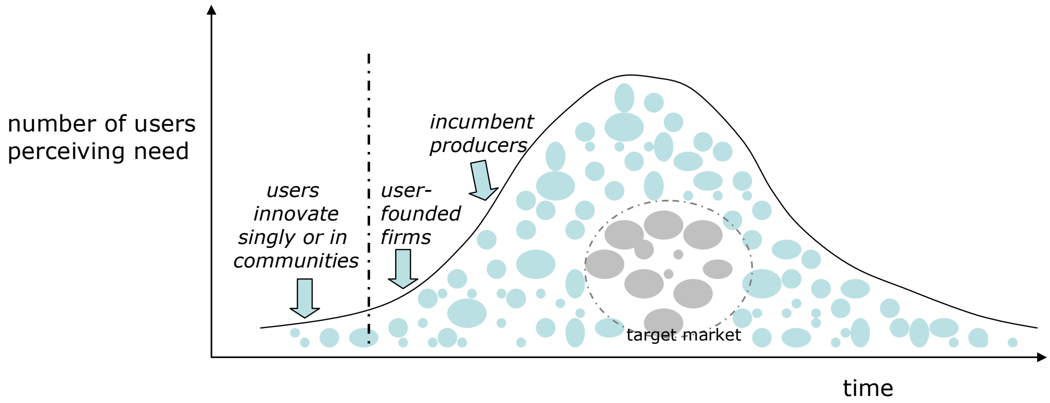
A common finding is that the frequency of user innovation is contingent on size (larger organizations are more process-intensive which calls for in-house innovation) and technical capability (for this reason a high share of user innovation was found in Dutch high-tech firms). In samples of end consumers the share of innovators is obviously smaller, but still reflecting millions of innovating individuals (Flowers et al., 2009).

In all, survey evidence shows that user innovation is found everywhere. Moreover, it is likely that user innovation will become more dominant in the near future – a process that has been emerging already in the past ten years. This shift is being driven by new technologies, specifically the transition to increasingly digitized and modularized design and production practices, coupled with the availability of very low-cost, Internet-based communication (Baldwin & von Hippel, 2009). These largely exogenous developments steadily increase the scope and richness of innovations that user innovators can design and develop, either on their own or in communities. They will be increasingly able to routinely apply sophisticated design tools (software) and computing power to innovate at costs that are trivial relative to comparable costs in the past.

2.4 User-centered model

Users innovate at the leading edge of emerging needs for new products and services, where markets by definition are both small and uncertain. Empirical research shows that users tend to be the dominant source of innovation with respect to functionally novel innovations, and that the frequency of user innovation in samples of firms and end consumers is substantial. The following user-centered model of innovation traces the pathway from the initial development of a new product by users through to commercialization by producers (Figure 2).

Figure 2. User-centered, alternative model of innovation



User innovation begins when one or more users of some good recognizing a new set of needs and/or design possibilities and begin to design and build and use innovations intended to better serve their own needs. If the innovation is of interest to additional users, one or more communities of user-innovators soon coalesce and begin to exchange information about their various designs, their experiences with them, and promising avenues for improvement.

Next, some time after user innovation begins, the first user-purchasers appear – these are users who want to buy the goods that embody the lead user innovations rather than building them for themselves. Some of the user innovators may decide to start their own businesses to satisfy other users' similar needs. The first producers to enter the market are likely to be user-founded firms, i.e. user-innovators who draw on the same flexible, high-variable-cost, low-capital production technologies they use to build their own prototypes.

As information about product designs becomes codified, and as market volumes grow, incumbent producers - both existing user-founded firms, established producers from other fields, and start-up producers who have identified the opportunity - can justify investing in higher-volume production processes involving higher capital investments. These processes have lower variable costs, hence their use will tend to drive prices lower and expand the market. User-purchasers then have a choice between lower-cost standardized goods and higher-cost, more advanced models that user-innovators continue to develop. User innovators will be present throughout the emerging industry's life cycle, because (established) producers will only serve homogenous target markets, so that at least some users will not precisely get what they want. Throughout the life cycle however, the role of producers versus users as a source of innovation will slightly change – user innovators will be most dominant in the nascent and early stages of industry emergence.

The user-centered model provides an alternative view of how innovation 'works'. Clearly, many innovations developed today are no result of a research-development-production-diffusion model. As we discussed, the user-centered model has been consistently documented in many cases and surveys, suggesting that the producer-centered model adequately describes innovation in (at best) only part of the real-world cases.

3. Legitimacy

This section is concerned with the legitimacy of policies for user innovation. In a neoclassical economic view, markets should be allowed to do their work of achieving optimal allocative efficiency. In policymaking it has accordingly been accepted that any intervention should be refrained from unless one has good reasons to do so. Common arguments for policy include the occurrence of spillovers (so that the social welfare effects of policy interventions exceed those of its direct beneficiaries) and failures. We will subsequently discuss why user innovation is marked by substantial spillovers, but also hampered by specific market and system failures disabling the user-centered model to reach its full potential.

3.1 Spillovers

A key argument to legitimize innovation policy is that eventually, everybody will benefit from it. Because of spillovers the social benefits of innovation exceed those of individual, innovating actors. These imply that not just the beneficiaries of innovation policies are advanced, but also external actors who do not invest or innovate at all.

Spillovers may relate to knowledge-, network- and rental effects (Jaffe, 1996; Griliches, 1992). Knowledge spillovers appear when knowledge that is developed by one actor becomes available to others, for example due to workforce mobility, publications, informal contacts or the reverse engineering of products. Such knowledge may inspire and enable others to initiate and implement more innovations. Network spillovers imply that technologies, which are developed in separate contexts, are complementary. An example is computer hardware and software which would be pretty useless without each other. Hence, producers see their potential revenues increase because of complementary innovative products, and users may see their utility improve due to better and more specific offerings. Finally, rental spillovers relate to improved price-quality ratios for users. Product innovation for example improves the quality of products, while the innovator will usually not manage to raise his prices to fully appropriate the rise in quality.

In the producer-centered model spillovers are achieved by selling new products to users, but also by spillovers which are involuntary from the producer's point of view. In the user-centered model, mechanisms of diffusion are quite different. If user innovations would not be diffused, multiple users with very similar needs would invest to (re)develop very similar innovations, which would be a poor use of resources from a social welfare point of view. Previous work however provides two arguments why user innovations are very likely to be diffused. First, users tend to develop innovations which are very attractive to others. Second, users tend to voluntarily reveal their innovations to others, implying that diffusion is implicit, and maybe even more likely than in the case of producer innovation.

As for the argument of attractiveness, we recall from section 2.2 that users possess different knowledge and develop different innovations than producers do. Users have a more accurate and detailed model of their needs than manufacturers have. They are more likely to develop innovations with new functionality. In contrast, manufacturers tend to develop improvements on well-known needs that require a rich understanding of solution information for their development (von Hippel, 2005). Thus, user innovators are anticipated to engage in radical innovations, while producers are more likely to develop incremental improvements to existing product lines, and this is what empirical studies suggest (e.g., Morrison et al., 2004). We also discussed that innovating users are most significant in the nascent and emerging stages of industries. Since they operate at the leading edge of markets, the novel products they develop for their own use are likely to be appealing to other users, and also to producers who may want to commercialize them (von Hippel, 2005). Indeed, lead user innovators appear to develop new or modified products with high commercial value (Morrison et al., 2004; Franke & von Hippel, 2003). The more generally useful their innovations, the more likely they will be adopted by producers to be commercialized (de Jong & von Hippel, 2009).

As for revealing, we recall that new and modified products developed by users often diffuse widely—and they do this by unexpected means: user-innovators themselves often voluntarily reveal to others what they have developed to examine, imitate, or modify without any payment to the innovator. Free revealing implies that user innovators voluntarily give up their potential intellectual property rights and share the details of their innovation with anyone interested, so that the information becomes a public good (Harhoff et al., 2003). The practices visible in open-source software development were important in bringing this phenomenon to general awareness. In these projects it was clear policy that project contributors would routinely and systematically freely reveal code they had developed at private expense (Raymond, 1999). However, free revealing has been documented in many other cases. Even user enterprises appear to reveal their innovations. In a survey of Dutch high-tech small firms, de Jong and von Hippel (2009) found that many user innovators do not mind if others take notice of their innovations, and most of them would allow strong ties in their networks to inspect and benefit from them. Likewise, in earlier work free revealing has been documented in more specific samples including the iron industry (Allen, 1983), mine pumping engines (Nuvolari, 2004), medical equipment (von Hippel & Finkelstein, 1979), semiconductor process equipment (Lim, 2000), library information systems (Morrison et al., 2000), sporting equipment (Franke and Shah, 2003) and embedded Linux software (Henkel, 2003). Users who freely reveal what they have done often find that others then improve or suggest improvements to the innovation, to mutual benefit (Raymond, 1999). Freely revealing users also may benefit from enhancement of reputation or positive network effects due to increased diffusion of their innovation (Lakhani & Wolf, 2005).

Due to their attractiveness and users' tendency to reveal, empirical surveys consistently find that user innovations diffuse to others. In a survey of Dutch high-tech small firms, de Jong and von Hippel (2009) found that one out of four innovations was adopted by producer firms. This was usually without any charge or, at best, an informal type of compensation (such as promises of reductions on future orders). Identical results were obtained in surveys of Canadian manufacturing plants (Gault & von Hippel, 2009) and small- and medium-sized firms and individual end consumers in the United Kingdom (Flowers et al., 2009). In sum, user innovation is marked by voluntary spillovers of highly attractive innovations.

3.2 Market failure

The argument of market failure stems directly from neoclassical economic theory, which considers markets as preferable mechanisms to achieve optimal allocative efficiency. Policy incentives should stress competition, and aim to reduce barriers to entry, growth and exit of enterprises. Market failure is said to be present when markets result in suboptimal outcomes, i.e. enterprises under-invest in innovative activities which results in a welfare loss (Arrow, 1962; Nelson, 1959).

Traditionally, theorists distinguish between four types of market failure, including 1. lack of appropriability, 2. uncertainty, 3. indivisibility and 4. asymmetric information (Gustafsson & Autio, 2006; Hauknes & Nordgren, 1999; Chaminade & Edquist, 2006). Each type will be elaborated on next. In advance, we remark that the producer-centered model is dominant in our thinking of market failures. Innovators are supposed to be triggered by economic incentives, and to benefit from innovations by trading them with other economic agents. However, users innovate primarily for themselves - market trade is far from a necessary condition. This implies that some market failures are not applicable to innovating users, but others do as we discuss hereafter.

First, lack of appropriation implies that actors are unable to fully appropriate the (market related) benefits from innovation (Chaminade & Edquist, 2006). In the words of Teece (1986: p. 285): 'It is quite common for innovators – those who are first to commercialize a new product or process in the market – to lament the fact that competitors/imitators have profited more than the one first to commercialize it'. In the producer-centered model, this is regarded as a serious disincentive, and to legitimize policies like intellectual property rights and R&D subsidies in order to actually reduce spillovers ('to stimulate spillovers we should give economic actors the institutional tools to reduce spillovers'). As we already discussed, user innovators are not concerned with appropriation too much. The empirical work so far has shows that user innovators think of spillovers as an opportunity, not a threat. In the early work of Allen (1983) it was argued that free revealing could be economically justified on several grounds, including (i) reputation gains, (ii) many people knew the information that it could not have been kept secret in any case, (iii) the innovation is to some extent specific to the innovator and so free riders would not gain advantage equal to that of the innovator, (iv) gains in the value of assets complementary to the use or production of the innovation, (v) free revealing may increase the innovator's profit by enlarging the overall market. More recently, it was documented for high-tech small firms that if there was any compensation, this was usually in terms of informal agreements with strong network ties (de Jong & von Hippel, 2009). In fact, intellectual property rights seem to disadvantage users as they may hamper the modification or creation of new products (see section 3.3.).

Second, uncertainty usually refers to producers' inability to know in advance what innovation will bring them (Chaminade & Edquist, 2006). It is quite common for innovations to fail as a result of technical problems or consumers' unwillingness to buy. Producers are in general reluctant to invest in innovation even if the expected value of their investments is slightly positive but uncertain. In contradiction, for users the issue of uncertainty is less problematic. Adoption by consumers is implicit, so only technical uncertainty remains. Like producers, users do not know in advance if their solutions will work. As discussed, they have superior need information, but are disadvantaged in terms of solution information (von Hippel, 1994). This creates opportunities for policies to better connect individual users or to involve producers as partners in innovation processes. In section 4, these matters will be elaborated upon.

Third, indivisibility traditionally relates to the fact that producer innovation can be pretty demanding in terms of monetary investments, and may require substantial initial investment to build and maintain a stock of knowledge required for innovation (Chaminade & Edquist, 2006). In the user-centered model, unlike appropriation and uncertainty, indivisibility can hamper innovation at least as much. The producer-centered model already recognizes that indivisibility is most problematic in small organizations. For individual users, it has been argued that if innovation design costs get too high, single user innovators are unable to innovate unless they manage to organize themselves in networks (Baldwin & von Hippel, 2009). In case of low-cost innovations or modifications of existing products that are justifiable based solely on the in-house use of a single innovator, users can well innovate for themselves. But when innovation expenditures get bigger, problems of investment coordination among users enter in. Compare, for example, a mountain bike and a full-fledged personal computer operating system. Individual users may be well able to develop and build their own bikes, but full-fledged operating systems may require too much. In this context, Benkler (2006) introduced the concept of 'granularity' to refer to the size of the modules, in terms of the time and effort that an individual must invest in producing them. As he notices: 'If the finest-grained contributions [to an innovation project] are relatively large and would require a large investment of time and effort, the universe of potential contributors decreases'(p.100-101). Hydrogen driven car engines for example would require an infrastructure to fill up, which is difficult for users to organize. This implies that at least some goods that users could afford are hampered by indivisibility. In such cases, policies to stimulate concerted efforts (as evidenced in many historical examples, but also in more recent cases like open-source software) or even financial incentives for user innovations may be legitimate.

Fourth, asymmetric information may hamper user innovation too. In the producer-centered model it implies that the distribution of innovation resources in society is inadequate. As a consequence, valuable innovation projects are not implemented. Producers may for example find it hard to persuade investors of the potential of their ideas, or fail to recruit technical staff in order to innovate (Chaminade & Edquist, 2006). For users, asymmetric information refers to the sticky information argument that we discussed in section 2. Users possess abundant need information, but are disadvantaged in terms of solution information. They may need producers' services in order to innovate, but qualitative evidence suggests that producers can be reluctant to recognize the value of user innovations (e.g., de Jong & von Hippel, 2009). Moreover, producers with solution information can be needed to effectively distribute innovations. In the case of information products, users have the possibility of largely or completely doing without the services of producers. In physical product fields, the situation is different. Users can develop products, but the economies of scale associated with manufacturing and distributing physical products give producers an advantage over 'do-it-yourself' users in those activities (von Hippel, 2005).

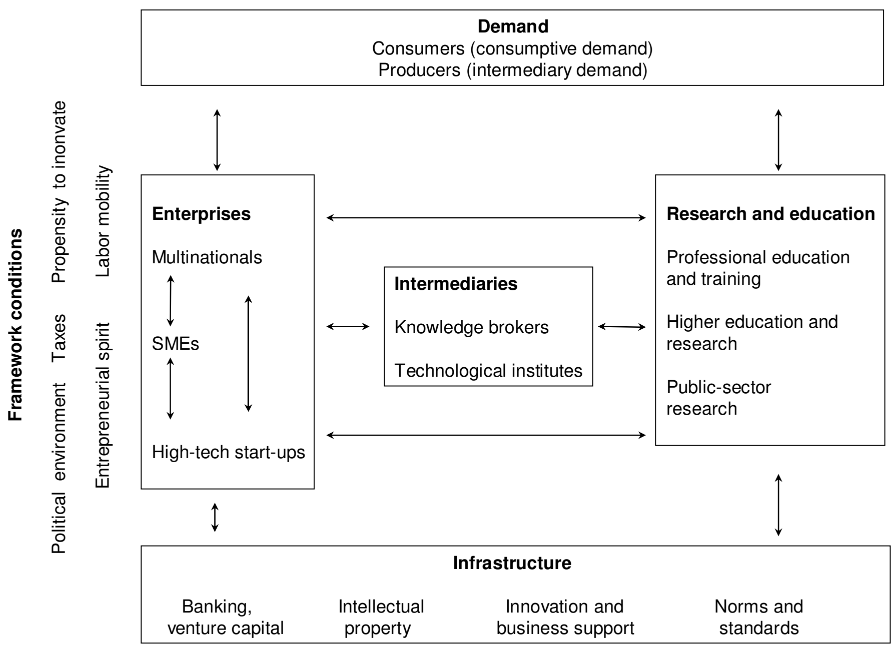
In summary, incumbent thinking of market failures seems partly applicable to justify policies for user innovation. Especially indivisibility and asymmetric information may prevent the user-centered innovation model to grow to its full potential.

3.3 System failure

In a world of producer-centered innovation, the literature on innovation systems provides more arguments to justify policy intervention (e.g., Tsipouri et al., 2008). In comparison with market failures, the systems literature assumes that under-investment in innovation is not exclusively due to poorly functioning markets, but can also be influenced by hampering factors in the 'innovation system', defined as 'all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations' (Edquist, 1997).

The systems literature (e.g., Nelson, 1987; Lundvall, 1992; Freeman, 1995) has a different view on how innovations come into being. Rather than a linear process it is proposed that innovation is the result of complex and intensive interactions between end users, enterprises, knowledge suppliers and intermediary parties (Arnold & Kuhlman, 2001). This process is influenced by infrastructural arrangements (such as the availability of finance, standards and legislations) and other external conditions including entrepreneurship and labor mobility. A graphical presentation of a national innovation system is given in Figure 3.

Figure 3. National innovation system



Source: Arnold & Kuhlman (2001).

The systems view implies that economic growth and social well-being are founded on well-functioning innovation systems, in which all actors need to perform. Both nodes and flows are important in innovation systems, since knowledge diffusion and spillover processes, combined with excellent absorptive and learning capacities among actors in the system, are key aspects of such systems. With the realization that knowledge producers may also be users, and vice versa, the idea of analytically partitioning knowledge-related activities into supply and a demand sides breaks down (O'Doherty & Arnold, 2003). Thus, the systems view deviates from the linear, producer-centered model of innovation, and accordingly provides better opportunities to justify policies in support of user innovation.

Producer-oriented theorists have identified four main types of failure which constitute crucial obstacles to the functioning of innovation systems: 1. capability failure, 2. network failure, 3. institutional failure and 4. framework failure (e.g., O'Doherty & Arnold, 2003; Gustafson & Autio, 2006; Tsipouri et al., 2008). In what follows, we explain that each of these failures can be anticipated to constrain user-centered innovation as well.

First, capability failures refer to the 'nodes' of the innovation system. Crucial actors in the innovation system may be weakly developed in terms of innovation capabilities. Producers can for example lack a sense of urgency or have poorly developed absorptive capacities. Similar issues are likely also hamper user-centered innovation. Users may not manage to innovate due to lack of technical skills or inability to devote time and other resources. Previous work shows that user innovators tend to have technical capabilities – a finding documented in case studies of scientific instruments (von Hippel, 1976), pipe hanger hardware (Herstatt & von Hippel, 1992), semiconductor processes (von Hippel, 1988) and oil refining (Enos, 1962). A survey in the Netherlands showed that high-tech small firms, being better equipped to develop their own innovations, were about 2.5 times more likely to be user innovators than regular small firms (de Jong & von Hippel, 2008). We also know from case studies that many more users have innovative ideas for what they want than have the capabilities to develop them – for example in mountain biking (Lüthje et al., 2002) and library information systems (Morrison et al., 2000). Thus, policies to further develop users' innovation capabilities would be legitimate.

Second, network failures bear on the 'flows' of the innovation system. Relationships between actors are not self-evident and may need to be triggered and supported (Gustafson & Autio, 2006). Users need to be able to connect with each other, and with relevant producers, for support and other assistance to develop innovations, and also for effective diffusion of their innovations. Von Hippel (2005) discusses a model in which multiple users may end up developing the same thing independently, concluding that it is more efficient to collaborate. In practice however, not all user innovators have the ability to connect. Survey evidence of high-tech small firms suggests that most users collaborate and share with their close network ties only (de Jong & von Hippel, 2008), a finding that was replicated for UK user firms (Flowers et al., 2009). Such network failure can be addressed by (online) horizontal user innovation communities which are nowadays seen in open-source projects. Horizontal networks of users would enable effective development of innovations by many individuals. In the case of information products this is anticipated to work nicely, but for physical products, producers would still be necessary because economies of scale are often involved in the production of copies of the physical innovation (von Hippel, 2007). In such instances, again, network failure will diminish the development and diffusion of user innovations.

Third, institutional failure relates to a disability to (re)configure institutions so that they work effectively within the innovation system. Institutions are 'sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations' (Edquist & Johnson, 1997). Examples of important institutions are intellectual property rights, as well as rules and norms influencing the relations between enterprises and consumers. Especially intellectual property rights (IPRs) seem important for the user-centered model to work well. It has been argued that patent laws and other IPRs, while designed to allow innovating producers to protect and benefit from their innovations, actually hamper users in their ability to modify and create new products – as they may infringe on producers' patents while innovating (Strandburg, 2008).

Fourth, framework failure implies that effective innovation depends partly upon regulatory frameworks, health and safety rules, etc. as well as 'other background conditions, such as the sophistication of consumer demand, culture and social values' (Edquist & Johnson, 1997). One striking framework failure that would justify policies for user innovation is in fact the dominant logic of current policy makers to focus on producer-centered innovation. All current innovation policies are tailor-made for organizations that benefit from selling innovations, rather than using them. This includes matters like IPRs, but also the requirement that projects supportable with government funds often require R&D expenditures. User innovation projects are often not organized or budgeted for in this fashion, as evidence shows for Canadian manufacturing plants (Gault & von Hippel, 2009) and Dutch high-tech small firms (de Jong & von Hippel, 2009).

We conclude that drawing on traditional notions, policies for user innovation can be justified. The user-centered model is marked by spillovers, which are unlike producer-centered innovation on a voluntary basis. The alternative paradigm also fits nicely with the innovation systems literature, as past work makes it plausible that user innovation is hampered by capability, network, institutional and framework failures. Even market failure theory, being designed to support the producer-centered model, provides a basis to justify policies for user innovation. Previous work clearly suggests that users find themselves constrained by indivisibility of (at least some) innovation expenditures and asymmetric information. Finally, a clear contradiction between both paradigms is seen in intellectual property rights, which are supposedly desirable in the producer-centered model, but a potential constraint for user-centered innovation.

4. Implications for policy

Despite scientific criticism today's innovation policies are dominated by interventions derived from the producer-centered, linear model (Godin, 2006). Indeed, developed countries focus on support for R&D cooperation, public-private partnerships, long-term research agendas, direct support for business R&D, support for innovative start-ups, knowledge transfer and support for public research organizations. Other, related policies focus on relieving barriers to producer innovation by providing innovation management and related advisory services, risk capital, and by addressing human capital – including the mobility of researchers, skilled personnel in enterprises, and career development of researchers (Tsipouri et al., 2008).

Researchers have only recently started to think of what user innovation implies for policy – so in advance we stress that it is important to start experiments to test the directions discussed hereafter. We will first present two general principles of user innovation policies. Next, seven directions for policymaking are discussed, including to 1. Stimulate networking and collaboration between users, 2. Facilitate the adoption of user innovations by producers, 3. Facilitate modular designs of innovations, 4. Improve individuals' technical skills, 5. Rethink intellectual property rights, 6. Explore a next generation of financial incentives and 7. Improve the measurement of innovation in official statistics.

4.1 General principles

In order to account for user innovation, it is first and foremost important that policymakers see through their dominant logic of what effective innovation policies should look like. Another general principle is that user innovation policies need to be eligible for individuals rather than just organizations. Both principles depart from incumbent policy makers' dominant logic as we will now elaborate on.

After dozens of talks in multiple countries, and attending various seminars with policy makers, we learned that those who hear about user innovation for the first time find it hard to capture its implications. A usual response is that 'users are a valuable source of innovation ideas for producers, but we already knew that'. Slightly better is 'we should make producers aware that users are not just a source of ideas, but rather some of them are capable of doing much more' or 'we need policy interventions to support enterprises to benefit from user-driven innovation'. From the perspective of the producer-centered model these responses make sense. Since it is generally assumed that consumers just consume, it may be hard to accept that policies can also directly target users. We however recall that there is consistent empirical evidence of widespread creation and diffusion of products by users themselves. Innovation by users is not the same as 'co-creation' processes in which users and producers work together in product development. Nor is it a form of 'user-driven' innovation in which producers pay close attention to user needs while developing new products for them.

The user-centered model of innovation is easily misinterpreted. An illustrative example is provided by the Danish Ministry of Economics and Business Affairs, who initiated as grant scheme for 'user-driven innovation' in 2007. They reserved an annual budget of 13 million euros advertised as 'A special program for user-driven innovation … allowing to build knowledge of customers and citizens. The program aims to contribute to achieving the goal of making Danish companies and public institutions more innovative. To obtain grants … projects must include and examine user needs in news ways. User-driven innovation is seen a way to [innovate] based on a systematic examination and inclusion of users' perceived and non-perceived needs. An improved knowledge of these needs can enable companies … to better target their R&D'[5].

Only organizations in the private and public sector are eligible for funding. Although the Danish intervention was inspired by user innovation theory, apparently the

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[5] See www.proinno-europe.eu/index.cfm?fuseaction=wiw.measures&page=detail&id=-1369.

dominant logic of the producer-centered model took over when it was designed and implemented. What remains is a traditional, producer-centered grant scheme to better account for the needs of users, which in practice turns out to be policy support for the application of mostly traditional marketing research methods. Such policies may be well received by Danish enterprises, but not in line with the user-centered innovation model.

A second restrictive element in incumbent policymaking is that usually only organizations are eligible for funding or support. Again, this makes sense from the producer-centered point of view. Producers, it is argued, are motivated to innovate by the expectation of profits. They eventually need to sell their innovations in order to benefit, so only commercial enterprises, self-employed and (in line with the linear model) public research organizations can be focal innovating actors. Such a view however ignores that user innovators can be any persons. Except for entrepreneurs, managers and individual inventors, they can be employees in non-R&D functions and individual end consumers. Policies for user innovation should not be eligible to firms only, but also to end consumers who may engage in open-source projects or individual innovative efforts while working from their very houses. Especially this latter element is a giant step from the incumbent policy makers' point of view.

We argue that the policy mix should be neutral in its intended effects on producers and users, rather than being advantageous on producers at the expense of users. In the next sections we present some guidelines that will be helpful to bring balance to the current policy mix – but in advance we stress that any attempt will be useless, unless the nature of the user-centered model and the necessity to account for individuals' behavior, are understood and accepted.

4.2 User networking and collaboration

A first direction for policy is to stimulate networking and collaboration between users. Innovation by users tends to be widely distributed rather than concentrated among just a very few very innovative users (von Hippel, 2007). As a result, it is important for user-innovators to find ways to combine and leverage their efforts. Users achieve this by engaging in many forms of cooperation. Direct, informal user-to-user cooperation (assisting others to innovate, answering questions, and so on) is common. Organized cooperation is also common, with users joining together in networks and communities that provide useful structures and tools for their interactions.

Networking and collaboration is also needed to effectively diffuse innovative products to other users. Producers partially achieve diffusion by selling their products (partially, because they diffuse the product incorporating the innovation, but often not all the information that others would need to understand it fully and replicate it). If user-innovators do not somehow also diffuse their innovations, multiple users with similar needs have to develop similar innovations independently (von Hippel, 2005).

Government actions to assist networking and collaboration include ensuring that widely-distributed potential innovation contributors have low-cost access to each other and to problems of interest to them being worked upon by others. Currently, the Internet already provides an infrastructure for many users to collaborate (Lakhani & Wolf, 2005) - consider open-source projects like Apache and commercial providers like Innocentive. To further stimulate this, policy makers should favor free Internet access, or low-cost access for those who currently lack it. Moreover, support for open standards and open interfaces is merited, so that participants in collaborative projects can innovate with the fullest information and the fewest interface constraints possible, and stimulate online facilities where users can post relevant need and solution information (von Hippel & Jin, 2009).

In the case of physical products, online collaboration is probably not enough. Although users can share and distribute product designs on the Web, joint problem solving usually demands physical presence in order to share sticky solution information. An example is the RepRap, an open-source 3D printer which can build any part (designed with a CAD software program) in layers of plastic. Many RepRap enthusiasts find themselves challenged by putting their machine together and to get it in operation. Although the RepRap community is quite successful in sharing and distributing codified knowledge on the Web[6], initial empirical evidence suggests that small communities in geographically concentrated regions are also needed, so that users can transfer tacit knowledge on how to start it up - a phenomenon that is missing in open-source software. To support geographically concentrated networks and collaborations, intermediary organizations may be helpful. Most developed countries nowadays finance public intermediary organizations to develop firms' innovation capabilities and to stimulate innovation networking (Howells, 2006). Examples include Syntens in the Netherlands, IWT in Belgium and Scottish Enterprise's Business Gateway[7]. Such organizations should refrain from being the main architect of networks and collaborations, but rather facilitate their self-organization.

4.3 Producer adoption

A second direction for policy is to facilitate the adoption of user innovations by producers. This would address information asymmetries that hamper the diffusion of innovations developed by users. In the case of information products, users have the possibility of largely or completely doing without the services of producers – the Web allows them to create, produce and diffuse complex products by and for themselves in the context of user innovation communities. In physical product fields however, the situation is different. Users can develop products, but scale economies give producers an advantage over 'do-it-yourself' users in production and distribution (von Hippel, 2007).

It is far from self-evident that producers adopt users' innovations. Most of today's producers still think that their job is to find a need and fill it rather than to sometimes find and commercialize an innovation that lead users have already developed. Accordingly, producers have set up market-research departments to explore user needs, and NPD teams to think up suitable products to address those needs. In this type of innovation environment, the needs and prototype solutions of lead users are typically rejected as outliers of no interest. Indeed, when lead users' innovations do enter a firm's product line they typically arrive with a lag and by an unconventional and unsystematic route. For example, a producer may 'discover' a lead user innovation only when the innovating user firm contacts the producer with a proposal to produce its design in volume to supply its own in-house needs (von Hippel, 2005).

[6] See www.reprap.org.
[7] See www.proinno-europe.eu.

We propose that policy makers could improve the interaction between users and producers along three lines. First, producers can be stimulated and taught to benefit from lead users. Second, producers can be supported to draw innovating users into joint design interactions by providing them with toolkits. Third, users can become entrepreneurs themselves in order to widely diffuse their innovations. We discuss each of these possibilities in turn.

Freely revealed innovative activities by lead users offers producers useful information about user needs embodied in solutions. Empirical work has shown that most NPD projects are unsuccessful (e.g. Cooper, 2003). Given access to a user-developed prototype, producers longer need to understand users' needs very accurately. Instead they have the much easier task of replicating the function of user prototypes that users have already demonstrated are responsive to their needs. For policymaking, informational campaigns on the potential value users in innovation processes – beyond market research and regarding users as a source of expressed needs only – may help to overcome such information asymmetries. Moreover, producers can be taught how to track lead users in their fields of interest. A natural experiment conducted at 3M for example showed that lead user product ideas and solutions generated more than 8 times the sales forecast for new products compared with traditional NPD projects (Lilien et al., 2002).

Producers may also involve innovating users in their innovation processes by offering 'toolkits for user innovation'. This involves partitioning product-development projects into solution-information-intensive subtasks and need-information-intensive subtasks. Need-intensive subtasks are then assigned to users along with a kit of tools that enable them to effectively execute the tasks assigned to them. In the case of physical products, the designs that users create using a toolkit are then transferred to producers for production (von Hippel & Katz, 2002). Empirical evidence shows that users' willingness to pay for self-designed products is much better (Franke & Piller, 2004). Most producers however seem reluctant to allow users to modify or tinker with their products. They may actually suppress user innovation by building technologies in their products that prevent any unintended use. For example, makers of ink-jet printers often follow a razor-and-blade strategy, selling printers at low margins and the ink cartridges used in them at high margins. To preserve this strategy, printer manufacturers want to prevent users from refilling ink cartridges with low-cost ink. Accordingly, they add technical modifications to their cartridges to prevent them from being refilled. This also excludes useful modifications, i.e. users refilling cartridges with special inks not sold by printer manufacturers to enable printing very high-quality photographs (Varian, 2002). Policy makers can intervene with informational campaigns, advisory services and educational programs to build awareness and remove such constraints.

Last but not least, innovations developed by users usually achieve widespread diffusion when those users become producers themselves - setting up a firm to produce their innovative products for sale. Shah (2000) first showed this pattern in sporting goods fields. In the medical field, Lettl and Gemunden (2005) have shown a pattern in which innovating users take on many of the entrepreneurial functions needed to commercialize the new medical products they have developed, but do not themselves abandon their user roles. Shah and Tripsas (2007) show that, in at least one field (the multibillion dollar juvenile products industry), 60% of all firms in the industry were founded by user-innovators. As we discussed in section 2, user entrepreneurship is seen most often in the early stages of industry emergence while incumbent producers enter somewhat later. However, user innovators are not necessarily equipped with great entrepreneurial capabilities, and policy interventions in support of user entrepreneurs may be needed. Such interventions would include coaching and advisory services on how to develop strategies, to bootstrap for external finance, to write a business plan, and more.

4.4 Modular designs

A third direction for policy is to facilitate modular designs of innovations. This would mainly address the failure of indivisibility of innovation objects, as discussed in section 3.2. In a recent contribution, Baldwin and von Hippel (2009) explain that collaborative open innovation projects – for example, as seen in open-source software – have major advantages over projects carried out by producers, and also over single user innovators. Because each participant can contribute a small part, the design costs of each contributor can be relatively low. In principle, given that the overall design tasks can be subdivided into small modules, and given enough interested participants, a design project of any size can be undertaken, even far beyond the kind of innovations that producers can handle. However, two conditions apply. First, communication costs are a major issue for collaborative open projects. Collaborators must communicate with one another to coordinate and compile their efforts. This means that low communications costs, as recently enabled by the internet, are critical to the viability of such distributed innovation – so for policymaking, internet access is again an important point of attention.

Second, to organize the distributed effort, but still coordinate the whole, the project needs a modular structure. An innovation is said to have a modular design if its parts can be developed independently but will work together to support the whole. Modules are distinct parts of the larger system, which can be designed and implemented independently as long as they obey the design rules. Thus, modules are units in an overall system design that are 'powerfully connected within themselves and relatively weakly connected to other units' (Baldwin & Clark, 2006). A policy issue is that current knowledge of modular designing may need to be supported in education. In polytechnics and technical universities, quite a few of today's engineering students are still taught to design in traditional ways. There is certainly no harm in subsidizing projects to stimulate modular designing in education, so that future innovators in businesses are better able to design products in such a way that they can harvest the 'power of the crowds'. Likewise, at least some end consumers will be provided with the design capabilities needed to potentially mobilize substantial numbers of co-developers.

With modular designs, there is no need to coordinate innovation time and money expenditures if each module provides an independent benefit worth its cost to the particular user-innovator. It gets to be a problem when such modularity cannot be achieved for some reason and takes a coordinated effort (for example, in the case of drugs or green technologies). Again, intermediary organizations may then have a role to play. Public investment in creating modularity in a specific field, for example investment in the development of specialized equipment, might be justifiable to reduce or eliminate problems with indivisibility in particular fields.

4.5 Technical skills

A fourth direction for policy is to improve individual citizens' technical skills. This helps to overcome capability failures of potential user innovators. As discussed in section 3, user innovators usually have technical capabilities, and there are more people having an idea for what they want than have the capabilities to implement them. Or in the words of Strandburg (2008): 'User innovation is not ubiquitous, of course. It is of greatest importance where users have both sticky information about their needs and the technical capacity to make inventions that fulfill those needs' (p.481).

From the user point of view, getting the capabilities is an infrastructure investment with project-specific costs on top. In general, this invites policy makers to stimulate people's capabilities for innovation. We here suggest two potential courses of action. First, policy should focus on an education system that is able to develop foundation analytical and problem-solving skills, creativity, imagination, resourcefulness and flexibility – education in technical specializations would be most important. This will support citizens' collective capacity to initiate, absorb, support, organize, manage and exploit innovation in its many forms. In this respect, it has already been identified that low public expenditures on scientific and engineering education is potentially very harmful (NESTA, 2006). Support for technical education at all levels, i.e. to attract large numbers of students, including primary, secondary and tertiary education, is recommended. Besides, as populations age and the half-life of training shortens, policy makers will need to address post-graduate training and 'lifelong learning' of a society's human capital as well.

Second, government actions to assist in capability development could include the development and diffusion of user-friendly computer-aided design tools that are central to collaborative innovation work conducted over the Internet (von Hippel & Jin, 2009). There is a lot of investment in toolkits that increasingly is sparing users from investment in general categories of infrastructural learning such as CAD-CAM tool training. It might be reasonable for government to support the development of these kinds of toolkits. Except for toolkits innovating users may also need access to specialized machinery for prototyping and initial production. Policy makers may initiate support programs in which users can access specialized machines at university labs or large commercial organizations, or alternatively, in community-operated physical spaces in which users sometimes manage to raise their own specialized equipment. Examples include the many FabLabs and Hackerspaces[8].

4.6 Intellectual property rights

A fifth direction for policy is to rethink intellectual property rights (IPRs). This issue is the very aspect of policymaking in which the producer- and user-centered models of innovation have conflicting interests, i.e. IPRs are introduced to relief producers' lack of appropriation, but from the perspective of users they represent an institutional failure.

A first remark is that many academics nowadays agree that producer-oriented IPRs often not have their intended effect. There are economies of scope in both patenting and copyright that allow firms to use it in ways that are directly opposed to the intent of policy makers and to the public welfare (Foray, 2004). Large firms are much better able

[8] See http://fab.cba.mit.edu/ and www.hackerspaces.org.

to patent their inventions and create 'patent thickets' - dense networks of patent claims that give them plausible grounds for threatening to sue at the expense of weaker competitors (Shapiro, 2001; Bessen, 2003). Movie, publishing, and software firms can use large collections of copyrighted work to a similar purpose (Benkler, 2002). In view of the distributed nature of innovation by users, with each tending to create a relatively small amount of intellectual property, users are as likely as small firms to be disadvantaged by such strategies. It is also important to note that users tend to build prototypes of their innovations economically by modifying products already available on the market to serve a new purpose. Laws such as the (U.S.) Digital Millennium Copyright Act, intended to prevent consumers from illegally copying protected works, also can have the unintended side effect of preventing users from modifying products that they purchase (Varian, 2002).

In order to make innovation policies neutral with respect to the sources of innovation, governments could pursue two directions. An elegant approach would be to target users themselves. Suppose that many elect to contribute their intellectual property to a commons in a particular field. If the commons then grows to contain reasonable substitutes for much of the proprietary intellectual property relevant to the field, the relative advantage accruing to large holders of this information will diminish and perhaps even disappear. At the same time, the barriers that privately held stocks of intellectual property currently may raise to further intellectual advance will also diminish. This possibility is supported by the creation and publication of standard Creative Commons licenses. However, reaching agreement on conditions for the formation of an intellectual commons can be difficult. Maurer (2006) makes this clear in his cautionary tale of the struggle and eventual failure to create a commons for data on human mutations. In such instances, government intervention can be helpful by offering intermediary services (possibly implemented by similar organizations as mentioned in section 4.2). Also, policymakers can add support of open licensing infrastructures to the tasks of existing intellectual property offices (Gault & von Hippel, 2009).

A more complicated direction would be to evaluate and redesign the current intellectual property regimes. Rather than continuously extending patent systems in terms of strength and enforcement, the user-centered model would benefit from a less stringent system. Strandburg (2008) recognizes that while innovating, users will often infringe on producers' intellectual property. She then recommends a blanket exemption from infringement liability for research use (p. 468). This would also better enable users to modify patented products in ways not anticipated by their patent holder. Another source of inspiration for a 'balanced' patent doctrine can be derived from the current regimes of plant breeder's rights. From the initial establishment of patent acts in the United States and in Europe, it has generally been felt that the patent system is inappropriate for protecting new plants. Consequently, special plant-tailored protection systems were created (van Overwalle, 1999) - and still in operation today. These systems are marked by exemptions for research purposes and even breeding purposes.

The research exemption implies that breeders can develop new varieties starting from existing (protected) varieties, but they cannot commercialize their new varieties without the consent of the plant variety rights owner (van Overwalle, 1999). Generalizing such an exemption would enable users to build on and modify incumbent technologies, as long as they do not commercialize their findings (at least, not without asking permission and negotiating an agreement first). Such an exemption would better enable users to innovate without being compromised by patent protection. The diffusion of user innovations may however still be limited – at least user entrepreneurs may be hindered by negotiations with patent holders.

The breeder's exemption is even broader, as it allows breeders to develop a new variety starting for an existing (protected) variety and commercialize it without the consent of the plant rights owner. Such a patent would definitely empower users to diffuse their innovations by means of new ventures, but we are aware that such exemptions are unlikely to be achieved in the policy arena. In sum, the plant variety rights system offers producers a weaker protection than the current patent doctrines, as it not only allows for research exemptions, but also for breeder's exemptions. Such a system would better account for 'infringement' acts done privately and for non-commercial purposes, and enable the rapid diffusion of user-developed innovations.

4.7 Financial incentives

A sixth direction for policy is to explore a next generation of financial incentives for innovation. Canadian evidence shows that lack of funds was one of two obstacles to (user) innovation most frequently identified as having high importance (Schaan & Uhrbach, 2009). This study also showed that most user firms do not finance their innovations from an R&D or formal innovation budget – implying that such expenditures are probably missed by current innovation subsidies. Indeed, recent survey evidence of user innovation by UK firms shows that only 6 percent of all user innovations was supported by some kind of public grant scheme or R&D tax credit (Flowers et al., 2009). At the same time, as we discussed in the previous sections, users often offer voluntary spillovers of their innovation-related knowledge that they have developed at their private expense, while their benefits are obtained from in-house use only. Some form of financial incentive for user-innovators might therefore be justifiable based upon similar reasoning used for producer-innovators. Such incentives will be cost-effective because potential user innovators are likely constrained by uncertainty about the technical feasibility or lack of modularity of innovations, but not by lack of appropriation or market uncertainty issues (as we discussed in section 3.2). We do not expect that user innovation incentives will require enormous policy budgets.

In terms of design, financial incentives would clearly differ from those offered in the producer-centered model. User innovations are developed more closely to the market. This implies that traditional grants or tax credits will not work as they potentially disturb market processes. We here propose four design elements. First, in the case of user-innovators, financial support must be linked to a requirement to freely reveal information sufficient to enable others to practice the same innovation – perhaps in the form of an 'anti-patent' that both proves novelty of claims and provides the information needed for others 'ordinarily skilled in the art' to practice the innovation that has been revealed. Alternatively, the innovation could be contributed to a commons or at least broadly presented so that any adopter cannot apply for a patent. Second, policies should account for the fact that most users innovate because they are intrinsically motivated to do so. Policies can account for this by offering recognition and fame, for example via awards and open competitions – note that free revealing is implicit for such types of incentives. Prizes and competitions are an elegant way of reducing the risk of unwillingness to reveal and abuse public funds in general. Third, financial incentives need to be eligible for individuals too. Financial incentives will be more neutral by being available to individuals (including employees in organizations and individual end consumers) and by not being limited to fundamental research projects.

Finally, governments could even institute tax credits or grant schemes analogous to those found in the producer-centered model, for innovators that freely reveal well-documented results of their private innovation developments. We are aware that such schemes are directly opposed to the dominant logic in current policymaking, but as long as all innovation results are revealed, serious harm is unlikely. Grant schemes could be organized as 'collective contracts' in which multiple users commit themselves to a distributed effort. A scheme that already comes close is the 'Innovation Performance Contracts' currently offered in the Netherlands. It is a grant scheme in which groups of (15-35) firms, usually from the same industry, agree to collectively invest time and resources in innovation [9]. In practice, most collaborations focus on user process innovations because competing firms do not like to collaborate on product innovation. One example is the development of lightweight boats to reduce fuel consumption by inland marine transport firms. If this scheme would become eligible for individuals and require to publicly reveal all results, it may be effective to support open, distributed innovations even when user participation is constrained by lack of modularity.

4.8 Measurement

A final direction for policy is to improve the measurement of innovation to reflect the user-centered model (von Hippel & Jin 2009, Gault & von Hippel 2009). User innovation is currently no part of official government statistics. The main international sources of indicators are the CIS (OECD, 2005) and R&D surveys (OECD, 2002). Both sources take the perspective of the linear, producer-oriented model. In this context, Jensen and colleagues (2007) conclude that in the EU's annual ranking of innovation performance of member states only traditional, linear innovation indicators are used, such as R&D expenditures, patenting, and the share of the population with tertiary education. According to Godin (2006) current measurement practices are the major reason that policy makers implicitly still favor the sequence of basic research, applied research, development and diffusion. It has therefore been proposed that current measurement practices need modification (e.g., Jensen et al., 2007; Godin, 2006; Laestadius, 1998).

We here suggest that official statistics should be modified in such a way that both producer and user innovation are adequately captured (in line with NESTA, 2006; Von Hippel & Jin, 2009). Until the actual levels of user innovation and expenditures are made clear, it will be difficult to get governments to take the policymaking needs of user innovators seriously.

Some might argue that user innovation indicators overlap with traditional indicators which are already part of the basic surveys, including process innovation. This however proves not to be the case (de Jong & von Hippel, 2008). The Oslo Manual - which guides statistical offices in collecting and interpreting innovation data with CIS surveys - defines process innovation as 'the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques,

[9] www.proinno-europe.eu/index.cfm?fuseaction=wiw.measures&page=detail&id=8966

equipment and/or software' (OECD, 2005: paragraph 163). It is not required to actually develop or modify any product, and indeed, user and traditional process innovation indicators do not show a strong overlap (de Jong & von Hippel, 2008). One other set of questions included offers a list of possible information sources ranging from 'clients' to suppliers to government labs, and asks respondents to rate the importance of inputs from each to their development efforts their innovation projects (OECD, 2005). Invariably the client (user) is ranked as supplying very important information by most producers. However, the problem with this question from the point of view of documenting the innovation role of users is threefold: the nature of the innovation remains uncovered, the terms of transfer are unclear, and the survey is directed to producers only, so we are only able to learn, even with improved questions, about innovations that users revealed to producers, and about user-producer transactions from producers' point of view.

Researchers have now begun develop and test new methods for collecting data on user innovation more accurately. Empirical surveys have been done to measure user innovation among samples of firms in Canada (Schaan & Uhrbach, 2009; Gault & Von Hippel, 2009), the Netherlands (De Jong & Von Hippel, 2008; 2009) and the United Kingdom (Flowers et al., 2009). The latter study was also first to document user innovation in broad samples of end consumers. In general, survey results shows that among small firms, the share of user innovators typically is 15-20%. For end consumers 8% was classified as a user innovator (Flowers et al., 2009). Another consistent result is that one out of four innovations developed by users is adopted by other users or producer firms. It is important to follow-up on the work that has been done so far.

5. Discussion

In this section we summarize our conclusions regarding the user-centered model of innovation. Next, we elaborate on its policy implications and give some further recommendations.

5.1 Conclusions

The dominant logic in today's innovation policy is one of producer-centered innovation. Policy makers assume that innovation is the province of producers, who can be either commercial enterprises or public research organizations. This may still seem a reasonable view, as producers are generally believed to effectively serve many users and to benefit from selling multiple copies of a single innovative design. However, the emergence of user innovation – and its open, distributed forms like open-source software in particular – is hard to reconcile with this traditional view. We therefore presented an alternative view of how innovation occurs, i.e. the user-centered model.

User innovators can be either firms or individual consumers that expect to benefit from using an innovative product. In contrast, traditional producer innovators expect to benefit from selling an innovative product. Thus, in order to profit, producers must sell or license knowledge related to innovations, or products incorporating their innovations. User-centered innovation processes are very different from the traditional, manufacturer-centered model, in which products and services are developed in a closed way, with the manufacturers using patents, copyrights and other protections to prevent imitators from getting a free ride on their innovation investments. In the manufacturer-centered model, a user's only role is to have needs, which manufacturers then identify and fill by designing and producing new products. Users that innovate can develop exactly what they want, rather than relying on manufacturers to act as their (often imperfect) agents. Moreover, individual users do not have to develop everything they need on their own: they can benefit from innovations developed and freely shared by others.

Under the user-centered model, economically important innovations are developed by users and other agents who divide up the tasks and costs of innovation development and then freely reveal their results. Users obtain direct use benefits from the collaborative effort. Other participants obtain diverse benefits such as enjoyment, learning, reputation, or an increased demand for complementary goods and services. As it appears, users innovate at the leading edge of emerging needs for new products and services, where markets by definition are both small and uncertain. Producers enter the market much later when a sufficient number of users has adopted the innovation, so that the presence of a homogenous group of consumers is given. The first producers to enter the market are likely to be user-founded firms, i.e. user-innovators who draw on the same flexible, high-variable-cost, low-capital production technologies they use to build their own prototypes.

A common finding in empirical research is that the frequency of user innovation is significant. Even individual end consumers have been found to innovate –a survey in the UK indicates that 8% of all consumers engages in user innovation. As for commercial enterprises, the share of user innovators varies from 15% (in a broad sample of UK small firms) to about 50% (in samples of Canadian manufacturing plants and Dutch high-tech small firms) (Flowers et al., 2009; De Jong & Von Hippel, 2009; Schaan & Uhrbach, 2009). We also anticipate that the user-centered model of innovation will be increasingly seen in the near future. This is due to two fundamental and undeniable trends: a. steadily improving design capabilities of users, made possible by increasingly sophisticated and affordable computer hardware and software, and b. improving ability of individual users to combine and coordinate their innovation-related efforts via new communication media such as the Internet (Von Hippel, 2005).

Policies for user innovation are legitimate for similar reasons as under the producer-centered model. In the user-centered model spillovers of knowledge are given, because most users do not mind to reveal their innovations to others. Besides, user innovation is likely to be constrained by capability, network, institutional and framework failures. Even market failure theory, being designed to support the producer-centered model, provides a basis to justify policies for innovation by users. Previous work suggests that users find themselves constrained by indivisibility of (at least some) innovation expenditures, and by asymmetric information, keeping producers from assisting them in the development and diffusion of innovations.

5.2 Recommendations

The ongoing shift of innovation to users has some very attractive qualities. It is becoming progressively easier for many users to get precisely what they want by designing it for themselves. Innovation by users also provides a very necessary complement to and feedstock for manufacturer innovation. In this context, Henkel and von Hippel (2005) concluded that innovation by users increases social welfare. They found that, relative to a world in which only producers innovate, social welfare is increased by the presence of innovations freely revealed by users. Users tend to develop new functionality which they require themselves. Producers can study these early user innovations to gain information about both emerging market needs and possible solutions that would be difficult to obtain otherwise. They can then advance the users' work by turning it into a robust product, producible at low cost. User innovation thus helps to reduce information asymmetries and increase efficiency of the innovation process. It can enable producers to provide a higher fraction of new products that are marketplace successes (Henkel & von Hippel, 2005). Thus, both models are complementary to each other. Product innovations developed by users will tend to fill small niches of high need left open by commercial sellers. User innovations are more likely to be different types of innovation, marked by functional novelty and better appeal to other users. And user innovation is characteristic for nascent and emerging industries.

Governments should balance the current policy mix by developing and implementing policies that account better for open, distributed and user-centered innovation. In order to adapt policies, we argued that two general principles need to be taken into account. First, it is important that policymakers see through their dominant logic of what effective innovation policies look like. The user-centered model is dissimilar from 'user-driven' forms of innovation in which producers pay close attention to user needs while developing new products for them. Second, user innovation policies need to be eligible for individuals, and not just organizations.

Next, in order to overcome the specific market and system failures that we identified, seven directions for policymaking need to be further explored. It is recommended to 1. Stimulate networking and collaboration between users, 2. Facilitate the adoption of user innovations by producers, 3. Facilitate modular designs of innovations, 4. Improve individuals' technical skills, 5. Rethink intellectual property rights, 6. Explore a next generation of financial incentives and 7. Improve the measurement of innovation in official statistics.

We are aware that adopting these issues is a giant step from the incumbent policies' point of view. It is however urgent because the anticipated and ongoing shift of product development activities to users can potentially wipe out incumbent producers. Open, distributed innovation is 'attacking' a major structure of the social division of labor. Many firms and industries must make fundamental changes to long-held business models in order to adapt – and policy support is needed to guide this too. On the other hand, we anticipate that as soon as the idea of user-centered innovation is accepted, new policy instruments can be implemented relatively easily. As far as financial incentives are involved, we anticipate that they will not be expensive – small amounts of money to overcome problems with indivisibility should do most of the job. Presumably the workings of the intellectual property (IP) system need most concern. This is the only aspect of current policymaking in which both models of innovation have direct conflicting interests.

We remark that researchers have only recently begun to explore the policy implications of open, distributed, user-centered innovation. Additional work on their legitimacy and effectiveness is called for. We recommend further work in three directions. First, as we discussed in section 4.8, the measurement of user innovation, and especially how it is reflected in official statistics, needs improvement. Current indicators need to be further developed and tested in bigger samples and in official government surveys like the CIS. Second, we need to know much more about what hampers user innovation, and what parameters policy makers need to focus on so that the user-centered model can reach its full potential. The kind of bottlenecks that (potential) user innovators encounter is an uncharted area of research. We expect that drawing on such a study more directions for policymaking can be formulated, in addition to the ones discussed here. Third, we recommend to start with policy experiments on a smaller scale to identify under what design conditions various interventions are effective. New indicators may also serve to test the effectiveness of new policy measures to support user innovation.

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