5 User innovation: business and consumers

Jeroen P.J. de Jong and Eric von Hippel

1. INTRODUCTION

Innovation is not only the domain of enterprises that seek to sell what they create. It is also done by firms and individual end users who wish to use what they create rather than sell it. User innovation is increasingly displacing producer innovation in many parts of modern economies, but official innovation indicators still do not capture the activity properly. This chapter discusses the distinguishing features of user innovation compared with traditional, producer-centered innovation, summarizes the empirical evidence, and reviews the state of the art in the measurement of user innovation.

Ever since Schumpeter (1934) introduced his theory of economic development, economists, policy makers and business managers have assumed that most important innovations originate from producers and are supplied to consumers through goods or services that are for sale. This view seems reasonable on the face of it; producers generally serve many users and so can profit from multiple copies of a single innovative design more than individual users would. In contrast, if individual users innovate, they could only depend upon their in-house benefits to recover their innovation investments. Presumably, therefore, a producer who serves many customers can afford to invest more in innovation than any single user could. From this, it follows that producer-centered innovation should dominate in most parts of the economy.

However, a second and increasingly important innovation model revolves around users who primarily innovate to satisfy their own needs, rather than to sell a product on the market (von Hippel 2005). Under this user-centered model, economically important innovations are developed first by users who divide up the tasks and costs of innovation development and then freely reveal their results. Users obtain direct use benefits from their efforts, and moreover, they may obtain benefits such as enjoyment, learning and enhanced reputations. User innovation is increasingly displacing producer innovation in many parts of modern economies (Baldwin and von Hippel 2011). A growing body of empirical work shows that users are the first to develop many and perhaps most new industrial and consumer products (von Hippel 2005). It has also been shown that substantial

shares of users engage in innovation, and that their innovations are generally unconstrained by intellectual property rights, in samples of consumers (e.g. von Hippel et al. 2011) and user firms (e.g. de Jong and von Hippel 2009). Moreover, by diffusing to other economic actors, user innovation increases social welfare (Henkel and von Hippel 2005). Finally, the importance of good and service development by users is increasing over time (Baldwin and von Hippel 2011). This shift is being driven by two related trends: (1) the steadily improving design capabilities (innovation toolkits) that advances in computer hardware and software make possible for users; and (2) the steadily improving ability of individual users to combine and coordinate their innovation-related efforts through communication media such as the Internet.

The shift towards a user-centered mode of innovation has implications for innovation management and policy. In this contribution, the implications of the user-centered model for the measurement of innovation are examined. Researchers have recently begun to develop and test new methods for collecting data on user innovation (e.g. Schaan and Uhrbach 2009; Flowers et al. 2010; Gault 2012), and stock is taken of their efforts so far. The discussion begins with the main distinctions between the user- and producer-centered models (Section 2). Then the empirical evidence collected in the past five years is summarized, showing that user innovation is widespread, often left unprotected, and apparently valuable to others as many user innovations are adopted by other users and/or producers (Section 3). Subsequently, stock is taken of how user innovation can be measured, reviewing various survey methods that have been applied to measure user innovation by user firms and by individual consumers (Section 4). The chapter ends with conclusions and suggestions (Section 5).

2. USER INNOVATION COMPARED WITH PRODUCER INNOVATION

Today, the dominant view of how innovation 'works' revolves around producers, here defined as anyone who would benefit from an innovative effort only if others adopted their innovation. In his early work, Schumpeter (1934) suggested that the economically most important and radical innovations are initiated by heroic entrepreneurs, and accordingly introduced by small and start-up enterprises. In his later work, he suggested that innovation takes place mainly in the R&D laboratories of large firms benefiting from a lack of competition (Schumpeter 1942). In both cases, however, innovations originate from producers and are supplied to

intermediate and/or end users through products that are introduced to a market for sale.

After Schumpeter, a multitude of alternative models of innovation have been introduced. Thus the linear model of innovation revolves around fundamental knowledge production and its valorization, postulating that innovation starts with basic research, with commercially promising research output moving to applied research, development and production, while market adoption eventually follows (Bush 1945). The demand-pull version of this model argues that innovation is driven by the perceived demand of potential users, and producers develop products in efforts to respond to customer problems or suggestions, while basic research is much less significant (Rothwell 1992). The chain-link model of innovation (and its predecessors) stresses that relationships between science, development, production and diffusion are complex and interrelated (e.g. Price 1965; Kline 1985). The doing, using and interacting (DUI) model emphasizes that, beyond systematic or interrelated knowledge production, innovation in enterprises is more often concerned with informal processes of learning and experience-based know-how (Jensen et al. 2007).

What remains is that all these models regard producers as key actors in innovation. Typical producer innovators include commercial enterprises and individual inventors (who all primarily benefit from selling their innovations), and public research organizations and universities (needing others to adopt their innovative output). Producer-centered innovation is also still very much present in today's statistical indicators and innovation policy practices. An alternative line of research that emerged in the past three decades, however, shows that innovation can also be done by firms and individual end users who wish to use what they create rather than sell it (von Hippel 1976, 2005). User innovation differs from traditional, producer-centered innovation in three respects: (1) how the innovator benefits from innovation; (2) type of knowledge involved and resulting innovations; and (3) diffusion mechanisms.

Benefit from Innovation

The main distinction between user- and producer-centered innovation is rooted in how innovators benefit from their innovation effort. User innovators can be 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. Firms or individuals can be both producer and 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 innovations in its machinery or production processes were investigated, the company could qualify as a user innovator. 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 producers must sell goods or services incorporating innovations.

In line with this distinction, users innovate if they want something that is not available on the market, and are able and willing to invest in its development; expected benefits from in-house use is what primarily drives them. In practice, many users do not find precisely what they need on existing markets. Meta-analyses of market segmentation studies suggest that user needs for products are highly heterogeneous in many fields (Franke and Reisinger 2003). As a consequence, some of them will modify their products or have a high willingness to spend time and money to develop a personal version of a product that exactly satisfies their needs. In contrast, producers tend to follow product development strategies to meet the needs of homogeneous 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' leaves many users dissatisfied with commercial products on offer (von Hippel 2005).

Type of Knowledge and Innovations

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: they possess superior information regarding their own needs. Producers must rely on market research to get a glimpse of those 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 about 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: 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'.

Users' and producers' differing stocks of local knowledge has an impact on the types of innovations that they 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 are more likely to be dimension-of-merit improvements, and not so much functionally novel innovations. 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.

Diffusion Mechanisms

A third important distinction is how producer and user innovations generally diffuse to other economic 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. However, producers cannot capture all the profits their innovations engender; their profits will be reduced by knowledge that involuntarily 'spills over' to other innovating actors as a consequence of labor mobility, site visits of external actors and other reasons (Griliches 1992).

In contrast, users often achieve widespread diffusion by freely 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 much about direct economic benefits

anyway. Other users may just pick what a user innovator has developed, or alternatively, a commercial producer may adopt his/her innovation to further develop it and introduce it to the market for general sale. Finally, some users may start their own businesses to commercialize innovations. They may find out that other users are interested, and become producers by themselves (Shah and Tripsas 2007).

3. EMPIRICAL SCOPE OF USER INNOVATION

Early user innovation studies focused upon narrow categories of innovations, leaving room for criticism that this type of innovation is a marginal one. For example, early studies demonstrated the significance of users as a source of functionally novel innovations in scientific instruments, automated clinical chemistry analyzers and pultrusion processes (e.g. von Hippel 1976). Likewise, studies on the share of user innovators initially focused on specific products like printed circuit CAD software, pipe-hanger hardware, library information systems and surgical equipment, while samples of individual consumers dealt with outdoor consumers products, extreme sports equipment and mountain biking equipment (for an overview, see von Hippel 2005: 20).

In the past five years researchers have started to develop indicators to identify user innovators in broad samples of firms and consumers – beyond specific products or industries. From this work initial conclusions can be drawn regarding the frequency, openness and diffusion of user innovations in the general economy. Here, the empirical evidence is briefly reviewed, while a discussion of their survey methods follows in Section 4.

Frequency

Recall that user innovators can be either firms developing equipment or processes for in-house use, or individual end consumers primarily innovating for personal need. Table 5.1 offers an overview of empirical studies in chronological order.

Samples of firms

Surveys of small firms generally find that 15 to 20 percent can be considered user innovators (de Jong and von Hippel 2008; Flowers et al. 2010; Kim and Kim 2011). Those firms developed at least one innovation in the past three years that was primarily motivated by internal, process-related needs. After extrapolation, this concerns millions of companies across the globe. Moreover, survey evidence suggests that

Table 5.1 Frequency of user innovation in broad samples of firms and consumers

Source	Country	Year	Sample	Frequency (%)
Firm surveys				
Arundel and Sonntag (2001)	Canada	1998	3702 manufacturing plants with > 10 employees	41.0
Schaan and Uhrbach (2009)	Canada	2007	6478 manufacturing plants with > 20 employees and $250K revenues	39.8
de Jong and von Hippel (2009)	Netherlands	2007	498 high-tech SMEs with < 100 employees	54.0
de Jong and von Hippel (2008)	Netherlands	2008	2416 small firms (< 100 employees)	21.0
Flowers et al. (2010)	UK	2009	1004 SMEs with 10–250 employees	15.3
Kim and Kim (2011)	South Korea	2009	3081 manufacturers with > 10 employees	17.7
Consumer surveys				
von Hippel et al. (in press)	UK	2009	1173 individual end consumers ≥ 18 years	6.1
de Jong (2011a)	Netherlands	2010	533 consumers ≥ 18 years	6.2
Ogawa and Pongtanalert (2011)	USA	2010	1992 consumers ≥ 18 years	5.2
Ogawa and Pongtanalert (2011)	Japan	2011	2000 consumers ≥ 18 years	3.7

Note: Reported frequencies are population estimates, with the exception of de Jong and von Hippel (2009) and Ogawa and Pongtanalert (2011).

substantial investments are involved. Flowers et al. (2010) followed up on firms' most recent user innovations by documenting their time and money expenditures. They found that for every user innovation, companies spent on average 107 person-days and £44 500 out-of-pocket costs. When evaluated at the average salary for UK workers, this represented an annual spending on user innovation of £1.7 billion. It was also estimated that the annual R&D spending by similar firms was £2.6 billion, indicating that investments in user innovation are not marginal.

In more specific samples of manufacturers and high-tech small firms the share of user innovators is higher, that is, in the 40 to 60 percent range (Arundel and Sonntag 2001; Schaan and Uhrbach 2009; de Jong and von Hippel 2009). Arundel and Sonntag (2001), for example, analyzed data on the adoption, modification and development of specific technologies by Canadian manufacturing plants. From their findings it can be inferred that 41.0 percent modified existing technologies to better fit their internal needs, or developed their own technologies from scratch for application in their operations.

The empirical studies so far suggest that the frequency of user innovation is contingent on firm size, industry types and technical capabilities. Larger organizations are more process-intensive, which calls for in-house innovation, and indeed, studies report that the frequency of user innovation increases with size (e.g. de Jong and von Hippel 2008; Flowers et al. 2010). For industry types, generally manufacturers are more process-intensive and likely to innovate for their own process-related needs (e.g. de Jong and von Hippel 2009). For technical capability, it has been found that high-tech firms are more likely to innovate (e.g. de Jong and von Hippel 2009). Finally, it should be noted that user firm innovation partially overlaps with process innovation as defined by the *Oslo Manual* (OECD/Eurostat 2005). An important distinction, however, it that user innovation is limited to new creations and/or modifications of existing processes, while process innovation also includes adoptions of equipment or processes developed by other parties that are new to the firm. A further elaboration follows in Section 4 (Firm Surveys).

Samples of consumers

User innovation by individual consumers is not at all recorded in official surveys, and until recently it could be considered dark matter: unmeasured, and so impossible to include in economic or policy-making analyses. Consumers may innovate in their leisure time to create and/or modify everyday items like craft and shop tools, sports and hobby equipment, dwelling products, gardening equipment, vehicle and transport-related items, pet-related items and medical equipment (von Hippel et al., in press).

The evidence so far suggests that about 4 to 6 percent of all consumers created at least one user innovation in the past three years (Table 5.2). Von Hippel and colleagues (in press) found a share of 6.1 percent innovating UK consumers, equivalent to 2.9 million individuals. They also found that these innovators on average spent 7.1 days and £1098 out-of-pocket costs per year. At the macro-level and when evaluating person-days at average UK workforce salaries, total annual spending by consumers on innovation was estimated at £3.2 billion. (For comparison, estimated annual R&D expenditures by companies on consumer products were estimated at £2.2 billion.)

Results from the consumer surveys mentioned in Table 5.1 include that, across the globe, hundreds of millions of consumers are user innovators, with probably substantial investments involved (especially when consumers' time spending is taken into account). Moreover, it has been found that the frequency of innovation by consumers is higher for males, and for those with high educational attainment and/or technical training (von Hippel et al. 2011). Obviously, education and training reflect personal capabilities for innovation: highly educated engineers are most likely capable of developing fixes for their personal problems.

Openness

Producer innovators would generally protect their innovation-related knowledge with intellectual property rights (IPRs) to exclude others and/or to facilitate licensing strategies. In contradiction, user innovators are not driven by profits that would result from selling their knowledge, and are often not rivalrous with potential users. Accordingly, users are less likely than producers to exclude others from adopting their knowledge. Moreover, the presence of innovating users does not always imply a big market of other users facing sufficiently similar needs. Producers generally employ product development strategies to meet the needs of homogeneous market segments, but user needs can be very diverse so that applying for IPRs is less useful. 'Open innovation' is here defined as innovation without claiming IPRs. In most of the surveys that were discussed above, researchers followed up by asking innovators if they had applied IPRs to protect their innovations – by patents, copyrights, trademarks and/or confidentiality agreements. See Table 5.2.

The share of innovating firms using IPRs for their user innovators ranges from 12.5 percent to 53.3 percent. In consumer samples this is much lower, ranging from 8.8 percent in the USA to even 0.0 percent in Japan. In general, user innovators are less inclined to protect their innovations with IPRs, most likely because they do not regard it as a source of profit. This becomes most evident when consumer samples are considered,

Table 5.2 Protection of user innovations with IPRs by firms and consumers

Source	Country	Year	Sample	Protection with IPRs (%)
Firm surveys				
de Jong and von Hippel (2009)	Netherlands	2007	364 user innovations developed by high-tech SMEs (< 100 employees)	12.5
Schaan and Uhrbach (2009)	Canada	2008	1277 user innovations developed by manufacturing plants with > 20 employees and $250K revenues	53.3
Flowers et al. (2010)	UK	2009	200 user innovations developed by SMEs with 10–250 employees	35.5
Kim and Kim (2011)	South Korea	2009	370 user innovations developed by manufacturers with > 10 employees	43.8
de Jong (2010)	Netherlands	2010	81 user innovations developed by high-tech SMEs (< 100 employees)	13.6
Consumer surveys				
von Hippel et al. (in press)	UK	2009	104 user innovations developed by consumers ≥ 18 years	1.9
Ogawa and Pongtanalert (2011)	USA	2010	114 user innovations developed by consumers ≥ 18 years	8.8
Ogawa and Pongtanalert (2011)	Japan	2011	83 user innovations developed by consumers ≥ 18 years	0.0

but also for high-tech small firms that are competing with differentiated products rather than unique production processes. In this context, de Jong (2010) presented data on 81 small high-tech firms that had engaged in both producer and user innovation in the past three years. While small high-tech firms were inclined to protect their new products (60.3 percent), the same firms did not bother about protecting their user innovations (only 13.6 percent applying for IPRs). For larger organizations, the findings are different. In the Canadian, UK and South Korean firm samples mentioned in Table 5.2, quite a few firms were eager to protect their knowledge. A possible explanation is that especially large manufacturers are more likely to operate in oligopolistic markets where competitive advantage revolves around unique production processes, and then it makes sense to exclude rivals from copying innovative processes. In general, however, user innovation seems more open than producer innovation.

Diffusion

From a social point of view, it is important that innovations diffuse across society. Knowledge spillovers appear when knowledge that is developed by one actor becomes available to others. When innovations are developed by producers, the pathway to diffusion is well known, as producers will sell what they have developed to all interested consumers and/or firms, or simultaneously, their knowledge may involuntarily spill over to other innovators and adopters.

User innovations should obviously diffuse too, or multiple users with similar needs would need to invest in similar innovations. This would be a poor use of resources from a social welfare point of view. In general, three mechanisms for the diffusion of user innovations include:

- peer to peer: users may reveal their innovations to others for inspection, copying and adoption, without charge, so that innovations diffuse peer to peer;
- producer adoption: commercial producers may adopt users' innovations to further improve and sell them as commercial products;
- new venture creation: innovating consumers may start a new business to introduce a commercial version of their innovation to the market, while innovating firms may further develop their user innovation into a new line of products which are then commercialized.

Free revealing

While many users do not bother about IPRs, some go further and actively reveal their innovations for free. They may do so hoping that commercial

producers will adopt and improve their innovations so that more robust and reliable solutions become available. Alternatively, free revealing can be driven by expected recognition of peers and reputation gains, communal norms of reciprocity (i.e. benefit from other users' contributions, as in open-source software) and desires to set informal standards (Harhoff et al. 2003).

After early studies demonstrated that users share their innovations, for example in medical equipment, open-source software, semiconductor process equipment, library information systems and mine-pumping engines (von Hippel 2005), recent studies find similar results in broad samples (e.g. Flowers et al. 2010).

Many innovations developed by users are of interest to the innovator only, or alternatively, the user does not bother about revealing the innovation for some reason (e.g. it is not considered of general interest, too much time is needed to reveal its design on the web etc.). However, in samples of firms about 10 percent of the user innovations are freely revealed. In consumer samples the share of innovations that are freely revealed is higher: in the 10 to 30 percent range (e.g. von Hippel et al. in press). Beyond this a subset of users reveals their innovations selectively, for example to their close social ties, and/or for non-monetary compensations such as promised discounts on future orders and other favors. For example, in a sample of user innovations developed by Dutch small high-tech firms, selective revealing applied to 13 percent (de Jong and von Hippel 2009).

Adoption by peers and/or commercial producers

Survey results regarding frequency of adoption are shown in Table 5.3. Note that most studies did not distinguish between adoption by producers and other users, but rather asked for adoption in a broad sense. In the samples of Dutch high-tech SMEs and Canadian manufacturing plants, adoption by commercial producers was around 25 percent of all reported innovations. Moreover, Schaan and Uhrbach (2009) found that another 25.3 percent was adopted by other users. For consumers these general adoption rates are lower, that is, 5 to 20 percent, but across the globe this still represents millions of innovations that are apparently useful to others. The only 'outlier' is the South-Korean sample, in which a few manufacturers reported that other businesses had picked up their inventions. Kim and Kim (2011) argued that this may be due to cultural reasons and the presence of hierarchically organized industry structures ('chaebols'). In summary, although most user innovations seem of interest to the innovator only and/or are known only to the innovator, it is generally found that 5 to 25 percent are adopted by others either in part or as a whole.

Table 5.3 Aadoption of user innovations by other actors (firms or consumers)

Source	Country	Year	Sample	Adoption (%)
Firm surveys				
de Jong and von Hippel (2009)	Netherlands	2007	364 user innovations developed by high-tech SMEs (< 100 employees)	24.7[a]
Schaan and Uhrbach (2009)	Canada	2007	1277 user innovations developed by manufacturing plants with > 20 employees and $250K revenues	26.3[a] ; 25.3[b]
Flowers et al. (2010)	UK	2009	200 user innovations developed by SMEs with 10–250 employees	19.5
Kim and Kim (2011)	South Korea	2009	370 user innovations developed by manufacturers with > 10 employees	3.2
Consumer surveys				
von Hippel et al. (in press)	UK	2009	104 user innovations developed by consumers ≥ 18 years	17.1
Ogawa and Pongtanalert (2011)	USA	2010	114 user innovations developed by consumers ≥ 18 years	6.1
Ogawa and Pongtanalert (2011)	Japan	2011	83 user innovations developed by consumers ≥ 18 years	5.0

Notes:
a. Adoption by commercial producers only.
b. Adoption by other users only.

New venture creation

If users develop an innovation that other people like, they generally receive requests from other users to build and provide them a copy. Users then sometimes decide to start their own business to commercialize their innovations, and accordingly become producers – although they were initially driven by personal need. Examples of entirely new industries that were born through such a process include juvenile products, rodeo kayaking equipment and dishwasher machines (Shah and Tripsas 2007).

Empirical studies demonstrating the relationship between user innovation and new venture creation include Shah et al. (2011) and de Jong (2011a). Shah et al. (2011) found that 46.6 percent of innovative start-ups in the USA which survived more than five years were founded by user innovators. De Jong, after an extensive screening procedure, obtained a sample of 33 Dutch consumers who had developed a user innovation in the past three years. Next, he analyzed how these innovators performed on various indicators adopted from the Global Entrepreneurship Monitor (GEM) (see Hartog et al. 2010). He found that user innovators are more likely to have entrepreneurial intentions and to engage in nascent entrepreneurship. Thus 15.2 percent expected to start a new business within the next three years, and 9.1 percent were actively involved in the process of business creation but had not yet received any income. Within the broad population of all Dutch consumers these percentages were 7.4 and 3.1, respectively. Both of these findings suggest that user innovation and entrepreneurship are correlated (obviously these findings do not prove causality). It may be that innovating consumers are more likely to recognize opportunities to build a business and then do so. Alternatively, user innovation and early-stage entrepreneurship may reflect people's general proactivity to take charge and pick up challenges and opportunities in life. More research is needed to explore how these concepts are related.

4. MEASUREMENT OF USER INNOVATION

Researchers have applied a range of methods to survey user innovation in samples of firms and consumers. Here, an overview is provided, starting with firm surveys, and then for consumers. Next, the alternative perspective of the diffusion of user innovations is discussed, and how this can be better captured in official statistics.

Firm Surveys

Three methods have been applied in the past five years to document user innovation in samples of firms. First, surveys of advanced manufacturing technologies (AMT) have been done in Canada. The second method draws on telephone surveys and has been applied in the Netherlands and the UK. The third method is a follow-up to the Community Innovation Survey (CIS), which has been implemented in South Korea and Mozambique.

Method 1: AMT survey and follow-up

An early survey identifying user innovation in manufacturing plants revolved around the Canadian AMT survey (Arundel and Sonntag 2001). Back in 1998, Statistics Canada sampled thousands of Canadian manufacturing plants with at least ten employees, the continuation of a program begun in the 1980s following the publication of von Hippel (1988) (Gault 2012). Among other questions, data were collected on the adoption, modification and development of specific technologies. Respondents were offered a list of 26 technologies, ranging from computer aided design (CAD) to rapid prototyping systems. For each technology they indicated if they currently used it in their plant, and if yes, they were asked how the technology had been introduced: by licensing it or buying it off the shelf, by modifying an existing technology, or by developing a new technology from scratch. It appeared that more than half of the surveyed plants were either technology modifiers or technology developers (Arundel and Sonntag 2001: 27–9). Although the authors did not use the term 'user innovation', their definitions of technology modifiers and technology developers fit with the concept.

In 2007, the AMT survey was updated by Schaan and Uhrbach (2009). Again, a substantial share of the manufacturing plants had engaged in technology modification and/or technology development. Schaan and Uhrbach went on to organize a follow-up survey to collect data on the user innovation process, registering variables such as time and money expenditures, collaboration partners and more.

Obviously, all survey methods discussed here have their pros and cons. The AMT survey is an existing source of data, providing a quicker route to capture user innovation in official statistics. The survey is based on very specific cues, so that it is less likely that respondents would misunderstand any questions or overlook relevant innovations. A drawback is that the AMT is not as widespread as the CIS (see later). Many countries do not implement it, or only with substantial time gaps. Moreover, its questions deal only with technology modification and/or development, so

the potential domain of user innovation in firms is not fully covered (e.g. consider organizational innovations for in-house use) and is probably most suitable for manufacturing industries. Finally, to collect detailed information on the innovation process, a follow-up survey is still needed.

Method 2: telephone survey

To more directly capture user innovation with specific indicators, de Jong and von Hippel (2009) piloted survey questions in a sample of high-tech SMEs. They utilized two indicators of the presence or absence of user innovation: (1) had the firm developed new process equipment or software for its own use; (2) had the firm modified existing process equipment or software for its own use within the past three years. Next, respondents were asked to select their most recent innovation and report what it was about (open-ended question).

This method gave rise to a second type of user innovation indicators that are collected by computer assisted telephone interviewing (CATI). Respondents first indicate whether they innovated in software or physical products, and if they created their innovation from scratch or by modifying an existing product. Next, the survey script follows up with open-ended questions to obtain a detailed description of what respondents have done, and why. These descriptions are then screened to eliminate 'false positives' – reported examples that are not in fact innovations. Finally, more false positives are eliminated through additional questions, for example if respondents know of equivalent products already available on the market, and if they developed their innovations for customers (which would make the example a product innovation). After being first applied in 2007 on small high-tech firms (de Jong and von Hippel 2009), this method has been further refined in broad samples of small and medium-sized enterprises (de Jong and von Hippel 2008; Flowers et al. 2010).

This method consists of a fully dedicated survey in which only user innovation data are collected, including process questions such as on collaboration, investments, application of intellectual property rights, free revealing of innovations and diffusion patterns. There is no need for follow-up surveys. Moreover, the CATI technique enables a rigorous screening procedure so that falsely reported innovations can be removed, making this method very suitable for academic purposes. A disadvantage is that any connection with official surveys (e.g. CIS) is lacking, making this method not an obvious candidate for the production of official statistics.

Method 3: CIS and follow-up

A third method is to use the CIS as a screening survey to trace potential user innovations. The usual question on the presence of process

innovation can be considered a first indication. If the response is positive, then respondents are asked if their enterprise developed the process innovation (1) by itself, (2) together with other enterprises, (3) by adapting or modifying processes originally developed by other enterprises or institutions, or (4) entirely by other enterprises or institutions (Chapter 1: Appendix). Gault (2012) explains that positive answers to options 1 and 3 suggest the presence of user innovation, while the second option might. To gain more information on user innovation in firms, there can be follow-up surveys that start probing whether respondents to options 1–3 are really user innovators. These follow-up surveys could also record innovation process variables such as collaboration, intellectual property, investments and more, comparable with how researchers have done this when using the AMT or telephone survey methods.

This CIS-based method has been applied by Kim and Kim (2011) in a sample of manufacturing firms with more than ten employees in South Korea. More recently, Zita and Lopes (2011) did the same on a smaller scale in the Maputo province of Mozambique. A main advantage of this method is that the CIS is widespread, providing an opportunity to quickly capture user innovation indicators in official statistics. A drawback is that it is assumed that the first step (identifying potential user innovators with the CIS) captures all relevant user innovation activity, which still needs to be empirically demonstrated. Simultaneously, the first step has been shown to provide many false positives (Kim and Kim 2011), so a follow-up is indispensable in order to provide precise data on the frequency of user innovation. This is an area for future research.

Consumer Surveys

Official social surveys that capture the activity of consumers modifying or developing goods or services to suit their needs are still lacking. Researchers have so far been concerned with developing, testing and improving, a process that is still going on today.

A first attempt was made by Flowers and colleagues (2010) in the UK, based on computer-assisted telephone interviewing. While collecting data from 1173 UK consumers aged 18 and over, their survey method was inspired by the UK survey of 1004 small firms mentioned in Table 5.1. The survey started asking respondents whether they had created and/or modified software in the past three years, then the same for the creation and/or modification of hardware. For each of these options open-ended questions were asked to exclude false positives (e.g. 'I bought a piece of Ikea furniture and put it together myself'). Additional false positives were eliminated through analysis of responses to two screening questions. If

respondents knew of equivalent products already available on the market, or if they had developed the innovation as part of their jobs, their claimed innovations were excluded. In effect, the survey was designed to identify only innovations with some kind of functional novelty that consumers had developed in their leisure time. After the UK survey, similar surveys were implemented among consumer samples in Japan and the USA, now using web survey tools instead of telephone interviewing (Ogawa and Pongtanalert 2011).

A next generation of consumer surveys was piloted in the Netherlands (de Jong 2011a) and Finland (de Jong 2011b). These pilots addressed some specific problems encountered in the UK. First, unlike business respondents, many consumers were not aware of what innovation may entail. As a consequence, more specific cues needed to be provided to support adequate recall. Drawing on six pilot surveys of 100 highly educated Finnish consumers each, de Jong (2011b) concluded that (rather than software versus hardware) eight specific cues provide more reliable data: (1) computer software; (2) household fixtures and furnishings; (3) transport and vehicle-related; (4) tools and equipment; (5) sports, hobbies and entertainment; (6) children and education-related; (7) help, care and medical; and (8) other (open-ended category). Second, it was found that in consumer samples the distinction between innovation modifications versus creations was less important. There is a gray area between the two, and asking respondents only for 'creations' gave nearly identical results. Third, web surveys were piloted to see if they would provide acceptable data, and they did. Although telephone surveys remain a 'gold standard', the possibility of web surveying is a potential cost saver in future data collection efforts.

De Jong (2011b) recommended five steps to identify user innovators in broad consumer samples. For each of the aforementioned cues, respondents first indicate if they have created it in the past three years (e.g. 'Did you create any computer software for personal need?'). If yes, up to four additional questions are asked to screen out false positives:

- Respondents indicate if they created it (e.g. computer software) for their job or business – to screen out job-related innovations.
- They then indicate if they could have bought a similar application on the market if they had wanted to – to screen out home-built versions of existing products.
- Next, they indicate if their primary motive was commercial rather than personal need – commercially driven innovations are discarded.
- Finally, respondents describe their innovation and its functional novelty (open-ended questions).

In conclusion, the measurement of user innovation by consumers is still in an early phase. State-of-the-art survey tools are currently helpful to inform academic studies, but they are not ready for adoption for the production of official statistics. One challenge is to reduce the number of questions, which may be done by asking extra advance screening questions. De Jong (2011b) identified two potential ones, related to tinkering and inventive activities. More specifically, he asked if respondents ever tinkered with machines, cars, computers or software in their leisure time, and if they ever spent their leisure time on inventions or developing new products, applications or concepts. If both answers were negative, the chances of being a consumer innovator became very small.

Diffusion of User Innovations

As the diffusion of user innovations is important for general welfare, the measurement challenge is to go beyond documenting the incidence of user innovation. While the aforementioned survey methods can include questions on diffusion, either directly (Method 2 and Consumer Surveys) or in a follow-up (Methods 1 and 3), the challenge can also be dealt with by modifying official surveys like the CIS.

Gault (2012) takes a different perspective by stressing the distinction between user innovation and user-driven innovation. User innovation, as discussed in Section 2, revolves around firms or consumers solving problems for personal need. User-driven innovation refers to the use by the producer of the flow of knowledge from the user as a result of using the product purchased. The producer may also collaborate with the user to co-innovate. These are cases of user-driven innovation, not of user innovation. In a recent contribution, Gault explained to what extent user-driven innovation is already present in official statistics.

While recalling that user innovations can diffuse through peer-to-peer sharing, producer adoption and new venture creation, Table 5.4 offers an overview of how the adoption of user innovations developed by firms and consumers is reflected in official statistics.

The left-hand column provides the case of user innovation by firms. If innovations are transferred to a producer (1a), or brought to the market by the user firm itself (1b), diffusion will sooner or later become evident in the frequency of product innovation as measured by the CIS. In the case of (1b), however, the source of innovation may be lost and additional questions and/or follow-up surveys would be needed to document if product innovations were first developed by users (Gault 2012). If user innovations are shared peer-to-peer (3a), process innovation numbers will go up.

Table 5.4 Diffusion of user innovation in official statistics

Diffusion mechanism	Type of user innovation	
	Firm modifies/develops a process (a)	Consumer modifies/develops product (b)
1. Producer adoption	Product innovation (user firm is source of innovation)	Product innovation (consumer is source of innovation)
2. New venture creation (or new product line)	Product innovation (user firm becomes producer)	Product innovation (consumer becomes an entrepreneur)
3. Peer-to-peer sharing	Process innovation in adopting firms (developed entirely by other enterprises or institutes)	Not yet visible in official statistics

Source: Derived from Gault (2012: 122).

Adopting firms would report a process innovation that is entirely developed by another enterprise or institute. Finally, in case the innovation is not transferred at all, the innovating firm itself would still report a process innovation (not in Table 5.4).

While official statistics are to some extent able to register the diffusion of firms' innovations, there are currently some serious shortcomings for user innovations developed by consumers. The right-hand column of Table 5.4 deals with this case. Again, in case of producer adoption (1b) and new venture creation (2b), statistics on product innovation should go up. But if consumers share their innovations peer to peer (3b), this is not considered innovation adoption according to the *Oslo Manual*. Gault (2012) suggests that the *Oslo Manual* definition of product innovation could be modified, that is, not limited to market introductions, but also include the situation when new products are made available to potential users, which does not necessarily happen through market mechanisms, but can also include sharing in a community of practice or peer group. It is suggested that paragraph 150 of the *Oslo Manual* should be modified to state: 'A new or improved product is implemented when it is made available to potential users', rather than 'when it is introduced on the market' (Gault 2012: 123), so that the CIS in the future could also capture the third mode of diffusion as far as diffusion to commercial enterprises is concerned.

5. CONCLUSION

User innovation is an alternative model of innovation, revolving around users who primarily innovate to satisfy their own needs, rather than for direct economic benefit. Recent evidence collected in broad surveys and in multiple countries shows that user innovation is present in large parts of the economy, practiced by millions of businesses and individual consumers. Substantial money and time investments are made by these innovators to satisfy their own process-related or personal needs, and this effort is not yet adequately recorded in official statistics (firms) or not recorded at all (consumers). Moreover, in consumer samples user innovation is very open (unconstrained by intellectual property), while early evidence for firms suggests that user innovation is at least more open than traditional producer innovation. Finally, user innovations appear to be useful to other economic actors. Diffusion mechanisms include peer-to-peer sharing (about 10 percent of the innovations developed by firms, and 10 to 30 percent of the innovations developed by consumers), new venture creation (user innovators are more likely to be occupied with early-stage entrepreneurship) and adoption by incumbent producers for further development and commercial sale.

In the near future user innovation will likely become even more important than it is today. Empowered by the Internet, specific types of user innovation, including open-source projects and other distributed forms of innovation, will be increasingly seen. Moreover, easy-to-use design tools such as CAD software and 3D printers will become more available, and as the average world education level is improving, an increasing share of world citizens will be able to innovate for themselves (Baldwin and von Hippel 2011).

This chapter suggests a research agenda. Researchers and policy makers could explore the implications of user innovation, starting with the current innovation measures. Today, the producer-centered model of innovation is still dominant in the thinking of both innovation researchers and policy makers, and current sources of innovation indicators do not yet (sufficiently) capture the concept of user innovation. Until the actual levels of user innovation and expenditures are made clear, researching and demonstrating its welfare implications and hampering factors will be complicated, and it will be difficult to get governments to take seriously any policy needs of innovating users.

In this vein, it has already been concluded that available indicators attract policy attention – think of the current focus in many countries on knowledge commercialization and continued interventions to stimulate R&D – and it has already been proposed repeatedly that current measures need modification (e.g. Jensen et al. 2007; Laestadius 1998).

To better capture user innovation in firms, more work could be done with the AMT and CIS-based methods, which would also include follow-up surveys to document how firms developed user innovations, and, more importantly, to what extent and how these innovations diffuse. Cognitive testing of the current questions in official surveys (e.g. process innovation questions in the CIS) is relevant and is the subject of a current OECD project (see Chapters 3 and 4). From the perspective of this chapter, the objective is that these questions more effectively serve as screening questions for detailed additional data collection, or may even be refined for this purpose. Finally, there are experiments with alternative survey designs to more directly measure user innovation in firms, using CATI methods. When doing so, the objective is to measure 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 bottlenecks that user innovators encounter are still uncharted.

As for surveying consumers, the activity and the resulting information are absent, as far as official statistics are concerned. The authors are not aware of any official survey that has tried to measure innovation by individual consumers, so this would be a logical next step. First, however, the current survey procedures need to be further refined and simplified. Current methods used by researchers and reported here have proven capable of tracing and validating reported user innovations, but are still too complex and labor-intensive to be suitable for official surveys. In addition, consumer survey methods have not been developed that can capture services innovations by users – while services have been identified as another field in which users are active developers of innovations with a high degree of novelty (Olivera and von Hippel 2011). In the coming years interesting new measurement practices and results emerging from the work that is currently in progress are anticipated.

REFERENCES

Arundel, A. and V. Sonntag (2001), 'Patterns of advanced manufacturing technology (AMT) use in Canadian manufacturing: 1998 AMT survey results', Research Paper no. 12, Science, Innovation and Electronic Information Division, Ottawa: Statistics Canada.

Baldwin, C.Y. and E. von Hippel (2011), 'Modeling a paradigm shift: from producer innovation to user and open collaborative innovation', *Organization Science*, **22**, 1399–417.

Bush, V. (1945), *Science: The Endless Frontier*, Washington, DC: US Government Printing Office.

Cooper, R.G. (2003), 'Profitable product innovation: the critical success factors', in L.V. Shavinina (2003), *The International Handbook on Innovation*, Oxford: Elsevier Science, pp. 139–57.

de Jong, J.P.J. (2010), 'The openness of user and producer innovation: a study of Dutch

high-tech small firms', paper presented at the User and Open Innovation workshop, Cambridge, MA, 2–4 August.
de Jong, J.P.J. (2011a), 'Uitvinders in Nederland' (Inventors in the Netherlands), Research Report A201105, Zoetermeer: EIM.
de Jong, J.P.J. (2011b), 'Identifying consumer innovators: a five-step survey procedure', Working Paper, Rotterdam: RSM Erasmus University.
de Jong, J.P.J. and E. von Hippel (2008), 'User innovation in SMEs: incidence and transfer to producers', Working Paper, Zoetermeer: EIM.
de Jong, J.P.J. and E. von Hippel (2009), 'Transfers of user process innovations to producers: a study of Dutch high tech firms', *Research Policy*, **38**(7), 1181–91.
Flowers, S., E. von Hippel, J. de Jong and T. Sinozic (2010), *Measuring User Innovation in the UK: The Importance of Product Creation by Users*, London: Nesta.
Franke, N. and H. Reisinger (2003), *Remaining Within Cluster Variance: A Meta Analysis of the Dark Side of Cluster Analysis*, Vienna: Vienna Business University.
Gault, Fred (2012), 'User innovation and the market', *Science and Public Policy*, **39**, 118–28.
Griliches, Z. (1992), 'The search for R&D spillovers', *Scandinavian Journal of Economics*, **94** (Supplement), S29–S47.
Harhoff, D., J. Henkel and E. von Hippel (2003), 'Profiting from voluntary information spillovers: how users benefit by freely revealing their innovations', *Research Policy*, **32**(10), 1753–69.
Hartog, C., J. Hessels, A. van Stel and J.P.J. de Jong (2010), 'Global entrepreneurship monitor 2009 the Netherlands: entrepreneurship on the rise', research report A201011, Zoetermeer: EIM.
Henkel, J. and E. von Hippel (2005), 'Welfare implications of user innovation', *Journal of Technology Transfer*, **30**(1/2), 73–87.
Jensen, M.B., B. Johnson, E. Lorenz and B.-Å. Lundvall (2007), 'Forms of knowledge and modes of innovation', *Research Policy*, **36**, 680–93.
Kim, J.B. and H.H. Kim (2011), *User Innovation in Korean Manufacturing Industries: Incidence and Protection*, Seoul: KAIST Business School.
Kline, S. J. (1985), 'Innovation is not a linear process', *Research Management*, **28**(2), 36–45.
Laestadius, S. (1998), 'The relevance of science and technology indicators: the case of pulp and paper', *Research Policy*, **27**, 385–95.
OECD/Eurostat (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, Paris: OECD.
Ogawa, S. and K. Pongtanalert (2011), 'Visualizing invisible innovation content: evidence from global consumer innovation surveys', Working Paper, June.
Oliveira, P. and E. von Hippel (2011), 'Users as service innovators: the case of banking services', *Research Policy*, **40**(6), 806–18.
Price, D.J.D. (1965), 'Is technology historically independent of science? A study in historiography', *Technology and Culture*, **6**(4), 553–68.
Riggs, W. and E. von Hippel (1994), 'The impact of scientific and commercial values on the sources of scientific instrument innovation', *Research Policy*, **23**, 459–69.
Rothwell, R. (1992), 'Successful industrial innovation: critical factors for the 1990s', *R&D Management*, **22**(3), 221–39.
Schaan, S. and M. Uhrbach (2009), *Measuring user innovation in Canadian manufacturing 2007*, Ottawa: Statistics Canada.
Schumpeter, J.A. (1934), *The Theory of Economic Development*, New York: Oxford University Press.
Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, New York: Harper and Row.
Shah, S.K. and M. Tripsas (2007), 'The accidental entrepreneur: the emergent and collective process of user entrepreneurship', *Strategic Entrepreneurship Journal*, **1**, 123–40.
Shah, S., S. Winston Smith and E.J. Reedy (2011), *Who are User Entrepreneurs? Findings on Innovation, Founder Characteristics & Firm Characteristics*, Kansas City, MO: Kauffman Foundation.

von Hippel, E. (1976), 'The dominant role of users in the scientific instrument innovation process', *Research Policy*, **5**(3), 212–39.
von Hippel, E. (1988), *The Sources of Innovation*, New York: Oxford University Press.
von Hippel, E. (1994), 'Sticky information and the locus of problem solving: implications for innovation', *Management Science*, **40**(4), 429–39.
von Hippel, E. (2005), *Democratizing Innovation*, Cambridge, MA: MIT Press.
von Hippel, E., J.P.J. de Jong and S. Flowers (in press), 'Comparing business and household sector innovation in consumer products: findings from a representative study in the United Kingdom', *Management Science*, doi: 10.1287/mnsc.1110.1508.
von Hippel, E., S. Ogawa and J.P.J. de Jong (2011), 'The age of the consumer-innovator', *MIT Sloan Management Review*, **53**(1), 27–35.
Zita, J. and A. Lopes (2011), 'User innovation in the Mozambican business enterprise sector for Maputo Province: presence of user innovation', Working Paper 2011-062, Maastricht: UNU-MERIT.