H200814

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Zoetermeer, September 2008

SCALES
SCientific AnaLysis of Entrepreneurship and SMEs

This report is published under the SCALES-initiative (SCientific AnaLysis of Entrepreneurship and SMEs), as part of the 'SMEs and Entrepreneurship programme' financed by the Netherlands Ministry of Economic Affairs.

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Incidence and Transfer to Producers

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Working paper
Draft version

Version October, 2008

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Abstract

The contribution of this paper is threefold. Firstly, we measure the incidence of user innovation in a broad sample of firms. Previous work has collected repeated evidence on the frequency of user innovation in a variety of industries and products, but so far its incidence has not been demonstrated in samples of larger business populations. Secondly, we assess if current innovation surveys adequately capture user innovation. Surveys such as the CIS (Community Innovation Survey) take a producer perspective and seem to overlook that in practice many innovation efforts are done by users to satisfy their process needs. Thirdly, we explore to what extent user innovations are transferred to producer firms. In doing so we assess if user innovation is marked by voluntary spillovers which is a strong argument to justify policies for user innovation.

Drawing on survey data of 2 416 SMEs in the Netherlands, we find that 21% of all SMEs engage in user innovation, i.e. they develop and/or significantly modify existing techniques, equipment or software to satisfy their own process-related needs. We also find that user innovation is remains largely invisible in the current innovation surveys. Next, in a survey of technology-based small firms in the Netherlands we identified 364 specific user innovations. We found that users tend not to patent or protect their innovations, and that one out of four is transferred to producers. The data suggest a significant feedstock of voluntary knowledge spillovers from users to producer firms. We conclude that future innovation surveys should explicitly capture user innovation, and develop some recommendations to guide this effort. We also plea for more research on policies for user innovation.

Keywords

User innovation, SMEs, producers, transfer, diffusion, measurement.

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1. Introduction

Previous work suggests that user innovation is an important kind of innovation, i.e. innovations are not solely developed by producer firms seeking profits or revenues, but can very well be realized by users facing specific process needs that current market offerings fail to meet. Despite that user innovation is visible in a wide variety of industries and product types, this form of innovation is basically overlooked in current innovation statistics and policies. A review of the European Innovation Scoreboard – an overview of the innovation performance of basically all European countries as well as Australia, Canada, Israel, Japan and the United States - shows that current innovation indicators do not capture user innovation at all. As for innovative output, the focus is on employment in high-tech industries and sales of new products, while innovative inputs are indicated by public and private R&D expenditures, general innovation expenditures and shares of innovating SMEs (European Commission, 2008). Besides, the inventory of innovation policy interventions of Pro-Inno Europe (capturing current policies of European and other OECD countries including the United States, Canada and Japan) shows that user innovation policies are barely implemented in September 2008 (see www.proinno-europe.eu). Only Denmark offers a program for user-driven innovation which is advertised as being primarily focused towards the roles of users in innovation processes.

The contribution of this paper is threefold. Firstly, we measure the incidence of user innovation in a broad sample of small and medium-sized enterprises (SMEs). Previous work on user innovation has collected repeated evidence on the frequency of user innovation in a variety of industries and products, but so far its incidence has not been demonstrated in samples representing larger business populations. Secondly, we investigate to what extent the current publicly funded innovation surveys capture user innovation. Surveys such as the Community Innovation Surveys (OECD, 2005) take a producer perspective, assuming that innovating actors are motivated by being more competitive and realizing growth and revenue objectives. We propose that adding user innovation indicators will change one's view of the innovativeness of firms and industries. Thirdly, we empirically explore to what extent user innovations are picked up by producer firms. In doing so we assess if user innovation is characterized by knowledge spillovers which is one argument for policy interventions related to user innovation.

The paper first takes stock of previous work on the incidence of user innovation, innovation measurement, and the transfer of user innovations, and develops propositions (section 2). Our empirical exploration is based on two surveys. We were able to participate in a survey of 2 416 SMEs in the Netherlands to measure the incidence of user innovation and to investigate the similarities and differences between user and traditional innovation indicators (section 3). We also conducted a survey of high-tech SMEs in the Netherlands to trace 364 specific user innovations. Here, we collected data on a range of topics, also including the transfer to producer firms (section 4). The paper ends with our conclusions and suggestions for future research (section 5).

2. Theory and propositions

2.1 Incidence of user innovation

User innovation refers to innovations developed by end users, rather than by producers. Users can be either firms or individual consumers, they are distinguished from producers by the fact that they expect to benefit from *using* a product or a service. In contrast, producers expect to benefit from *selling* a product or a service (von Hippel, 2005). A firm or an individual can be either a producer of user in specific situations. For example, Sony is a manufacturer of electronic equipment, but it is also a user of machine tools. With respect to the innovations that it develops for its electronic products, Sony is considered to be a producer, but if we would investigate innovations in its machinery or production processes, the company could qualify as a user innovator.

Qualitative observations have long indicated that producers do not maintain a monopoly on innovation. Rather, users are well able develop innovations, and these innovations may even be more important in terms of newness and disruptive effects. 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"*.

Users primarily innovate to satisfy their process-related needs which producers are (initially) unable or unwilling to solve. User innovators tend to be found at the early stages of the life-cycles of products, technologies and industries, i.e. history shows many examples of products which were initially developed by users striving to satisfy their own, process-related needs. Only later firms started to produce these products in larger volumes to serve groups of firms and/or individuals. Examples include airplanes, medical instruments, wifi antennas and kite-surfing and mountain-biking equipment, to mention only a few (von Hippel, 2005).

User innovation has so far been studied for a wide range of industrial product types where innovating users are user firms, and also in various types of sporting equipment, where innovating users are individual consumers. These studies show that substantial shares of users innovate, including printed circuit CAD software (Urban and von Hippel, 1988), pipe hanger hardware (Herstatt and von Hippel, 1992), library information systems (Morrison et al., 2000), surgical equipment (Lüthje, 2003), Apache OS server software security features (Franke and von Hippel, 2003), outdoor consumer products (Lüthje, 2004), extreme sporting equipment (Franke and Shah, 2003) and mountain biking equipment (Lüthje et al., 2002). The frequency with which user firms and individual consumers develop or modify products ranges from ten to nearly 40 percent (von Hippel, 2005).

However, these empirical findings cannot be considered representative for larger populations – the type of populations typically covered by publicly funded innovation surveys. Previous studies may be influenced by selection bias. As von Hippel (2005) notices: *"each of the studies looked at innovation rates affecting a particular product type among users who care a great deal about that product type (…) university surgeons care* *a great deal about having just-right surgical equipment, just as serious mountain bikers care a great deal about having just-right equipment for their sport. As the intensity of interest goes down, it is likely that rates of user innovation drop too"* (p. 20). Empirical attempts to measure the incidence of user innovation in broad samples are scarce. We are aware of only one case, which is the survey of Advanced Manufacturing Technologies (AMTs) that Statistics Canada implemented in 1998. This survey focused on a sample of Canadian manufacturing firms with at least 10 employees. Amongst other questions, it collected data on the adoption, modification and development of specific technologies (Arundel and Sonntag, 1999). A key finding was that 46 percent of the surveyed manufacturers bought AMTs 'off the shelf' only. Twenty-six percent also modified these technologies, and 28 percent even developed their own specific technologies because there was no market supply. A drawback of this study is however that services industries and the smallest firms – with 10 or less employees – were not covered. Small firms make up over 90 percent of any business population, and they contribute most to employment and employment growth. Likewise, services industries represent an ever-increasing share of value added in most economies and all developed countries see their business populations become increasingly oriented towards services (European Commission, 2003).

In the current paper, we measure the incidence of user innovation in a sample of SMEs in the Netherlands, including both manufacturers and services firms. SMEs are defined as firms with no more than 100 employees, but excluding self-employed business owners without staff. Given the findings of previous empirical studies, we anticipate

P1: There is a substantial share of user innovators among SMEs, i.e. in the range of 10 to 40 percent.

We also anticipate that the incidence of user innovation will vary across industry types and size classes. For industries, manufacturing firms tend to be more process-intensive, implying that there will face more opportunities for user innovation. Manufacturing processes are marked by explicit production lines and substantial capital investments in machines and other equipment. In services, the distinction between products and processes tends to be blurred. Services are more labor-intensive and its production processes occur simultaneously with delivery and consumption (Shostack, 1984; De Brentani, 1991).

For size classes we have similar suppositions. The larger the firm, the more it is characterized by production processes which give the opportunities to engage in user innovation. Growing organizations experience an increased need to formally organize their work and production processes in order to prevent internal crises (Greiner, 1972; Churchill and Lewis, 1983). Past economical work has shown that larger firms are more likely to benefit from process-related innovations. They are more process-intensive and their returns to process-related innovation investments, as compared to product-related investments, are generally better (Cohen and Klepper, 1996). We propose

P2: In manufacturing the share of user innovators will be larger than in services industries.

P3: In larger SMEs the share of user innovators will be larger than in smaller SMEs.

2.2 Innovation statistics

Over the past twenty years, models of innovation emphasize that innovation is an interactive process in which firms interact both with customers, suppliers and knowledge institutions (e.g., Kline and Rosenberg, 1986; Lundvall, 1992). Despite the broad acceptance of this literature, policy makers are blamed for still considering innovation processes as being connected to formal processes of R&D, especially in the science-based industries. This becomes visible in an emphasis on benchmarking variables related to 'science, technology and innovation' and in a focus on policy measures like R&D subsidies and programs to strengthen university-industry linkages (Jensen, Johnson, Lorenz and Lundvall, 2007).

Similarly, today's innovation surveys are criticized for having too much focus on the linear model of innovation as a theoretical background and being too narrow (Salazar and Holbrook, 2004). Jensen and colleagues (2007) for example conclude that *"policy makers' understanding of innovation could be considerably improved when innovation metrics better reflect the informal learning aspects of innovation by better capturing firms' using, doing and interacting behavior"* (p. 690). In this context, Laestadius (1998) conducted in depth case studies in the Swedish pulp and paper industry, and found that current innovation surveys gave too much weight to science and technology indicators, especially R&D expenditures. This caused a bias in the innovativeness of industries because development costs remained underreported and/or they were accounted as other types of costs. NESTA (2006) concludes that current innovation metrics implicitly follow a model of innovation that has little relevance to the modern world, and that current indicators result in biases towards R&D-intensive industries.

We here explore if user innovation indicators would change our view of the innovativeness of firms and industries. Echoing previous empirical work on user innovation, two forms of user innovation are distinguished. Users may either *modify* existing techniques, equipment or software to better satisfy their own needs, or they may *create* their own techniques, equipment or software from scratch because there is no market supply (von Hippel, 2005). From a distance, these forms of user innovation may overlap with traditional indicators for process innovation which are part of basically any public innovation survey. 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, equipment and/or software"* (OECD, 2005: paragraph 163). Besides, process innovation also includes *"new or significantly improved methods for the creation and provision of services. They can involve significant changes in the equipment and software used in services-oriented firms or in the procedures or techniques that are employed to deliver services"* (ibid paragraph 167) and *"new or significantly improved techniques, equipment and software in ancillary support activities, such as purchasing, accounting, computing and maintenance"* (ibid paragraph 168). Importantly, the Oslo Manual sets a low threshold for what qualifies as an innovation: *"the minimum requirement (…) is that the (…) process (…)must be new or significantly improved to the firm. This includes (…) processes and methods that firms are the first to develop and those that have been adopted from other firms or organizations"* (ibid paragraph 148).

It may be tempting to suppose that process and user innovation indicators are nearly identical. However, since the definition of process innovation is very broad and does not demand any development activity by the firm, we anticipate that process innovation indicators result in much higher shares of innovating firms. To qualify as a process innovator, it is sufficient to just adopt a piece of technique, equipment or software, while user innovation demands some kind of modification or creation. We expect that in any sample of firms, the share of process innovators will be higher than the share of user innovators. More specifically, user innovators are probably a subset of the process-innovating firms as identified by the Oslo Manual. Thus

P4: In samples of SMEs the share of user innovators will be smaller than, i.e. a subset of, the share of process innovators.

We suspect that user innovation would reveal much more directly how firms innovate, that is, if firms are adopters, modifiers or creators of new techniques, equipment or software. It must noted that the current process innovation indicators from the CIS have received substantial criticism. In 2003, the Belgian statistical office for example concluded that the concept of process innovation is ambiguous (Teirlinck, 2003). Drawing on a comparison of pen-and-paper and personal surveys, dissimilar shares of process innovating firms were found. In personal interviews, the interviewers were able to explicitly define process innovations and to explain what was meant. In this context, a recent report by NESTA (2007) provides evidence that in supposedly low-tech industries, a lot of innovation is going on which is not captured with traditional indicators. They plea for better metrics to reveal 'hidden' innovation in firms and industries. We here propose

P5: User innovation indicators give a different, more nuanced view of the innovativeness of firms and industries than process innovation indicators do.

2.3 Transfer to producers

Empirical evidence so far suggests that user innovations are more likely to be breakthrough innovations with disruptive effects – the most influential type of innovation in terms of macro-economic effects. Users tend to develop innovations that are functionally novel, as they are most aware of where and how current techniques, equipment or software fail to meet their needs. In contradiction, producers tend to develop innovations that are improvements on well-known needs, but in which they can apply their superior engineering and design skills to increase robustness, sustainability and technical quality (von Hippel, 2005; Ogawa, 1998; Lilien, Morrison, Searls, Sonnack and von Hippel, 2002).

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. This is in fact a common argument to justify innovation policies, i.e. the social benefits of innovation exceed the benefits of individual, innovating actors (Gustafson and Autio, 2006). 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. Besides, their knowledge will involuntarily spill over to other innovating actors as a consequence of labor mobility, site visits of external actors, and other reasons (see Griliches, 1992; Jaffe, 1996). 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, also because user innovations tend to be more disruptive than producer innovations.

Now, previous work finds that producers and users have different perspectives on how to deal with their innovative knowledge. Where producers are likely to appropriate their innovations by applying for intellectual property rights (IPRs), users are likely to reveal their innovations (Harhoff, Henkel and von Hippel, 2003). This is for various reasons, including for example that many user innovations are initially very specific and not necessarily developed in such a way that the needs of larger market segments can be immediately satisfied. Moreover, individual users tend to be unable to benefit from IPRs. Patent for example require substantial application and maintenance fees while revenues are uncertain and usually not realized. Users may rather hope that producers adopt their innovations to further develop them, in anticipation of more robust and reliable solutions compared to a 'home built'. So

P6: User innovators tend not to apply for intellectual property rights to protect their innovations.

As an alternative to formal IPRs, secrecy is not likely to be a sensible alternative. Other users often have similar knowledge and may be able to produce similar innovations. Even in the unlikely event that a secret is held by one individual, that information holder will not find it easy to keep a secret for long due to involuntary knowledge spillovers. In this context, Mansfield (1985) has found that the period during which intellectual property can be held secret is quite limited. More importantly, users face positive incentives to reveal their innovations, including recognition by peers and reputation gains, communal norms which prescribe reciprocity (i.e. benefit from other users' contributions like in open-source software) and desires to set informal standards (Harhoff et al., 2003).

Specific studies which have demonstrated that user innovations are shared with others have been done for medical equipment (von Hippel and Finkelstein, 1979), the iron industry (Allen, 1983), open source software (Raymond, 1999; Henkel, 2003), semiconductor process equipment (Lim, 2000), library information systems (Morrison, Roberts and von Hippel, 2000), sporting equipment (Franke and Shah, 2003) and mine pumping engines (Nuvolari, 2004). Again, empirical evidence is available only for specific products and industries. We here aim to measure to what extent user innovations are transferred to producers in a broader sample. This will indicate to what extent user innovation are marked by voluntary knowledge spillovers – which is important from a social point of view, and an argument to develop policies in support of user innovation. We anticipate

P7: User innovators are willing to share their innovations, and a considerable number of user innovations is transferred to producer firms.

They may also be differences between industries and size classes in the extent to which firms see their innovations transferred to producers. In services industries, production and delivery processes are characterized by frequent interactions with customers and other external parties. Services tend to be intangible, perishable and simultaneously produced and consumed (Shostack, 1984; De Brentani, 1991). Besides, services generally demand less capital investments, and accordingly they are easier to develop interactively without financial constraints. We could anticipate that service firms are more willing to freely reveal their innovations, simply because secrecy is an unrealistic option to them (while in manufacturing, technical solutions may be literally kept behind doors). Besides, the services sector contains many IT firms, a large and growing type of business. IT services firms are the most likely contributors to open-source software communities which are characterized by voluntary sharing (Lakhani and Wolf, 2005; von Hippel and Von Krogh, 2003). Finally, we mention that Harhoff et al. (2003) have identified the costs to adopt user innovations as one of the determinants of free revealing. As a rule-of-thumb, high adoption costs correlate with decreased likeliness to reveal. In labor-intensive services the adoption costs of innovations are probably lower than in capital-intensive manufacturing industries. So

> P8: In comparison with manufacturers, user innovators in services are more willing to share their innovations and more likely to see them transferred to producers.

For the size of firms, the innovation has repeatedly argued that small firms organize their innovation processes differently. They are hampered by modest financial resources, and they need to interact with their environment much more intensively to obtain the finance and knowledge needed for innovations (Vossen, 1998; Nooteboom, 1994). In such an environment, secrecy and formal IPRs are less realistic options, and smaller firms may rather decide to reveal their innovations, or at least not be bothered to protect them. We anticipate

> P9: In comparison with larger SMEs, user innovators smaller SMEs are more willing to share their innovations and more likely to see them transferred to producers.

3. Survey of SMEs

To empirically explore our propositions, we relied on two surveys. The first survey, as reported in this section, covered a broad sample of SMEs in the Netherlands. We used it to explore our propositions P1-P5. The second survey focused on high-technology SMEs only. We identified specific examples of user innovations in these firms, and asked detailed questions on how these innovations were developed, how much was spent, and – in line with our propositions P6-P9 – if and how these innovations were transferred to producer firms. These results are presented in the next section of this paper.

3.1 Sample

This survey was organized by EIM Business and Policy Research, a Dutch institute specialized in small business research. Commissioned by the ministry of Economic Affairs, EIM annually implements a survey to measure how SMEs organize their business processes, information that is not available in publicly funded statistics as provided by Statistics Netherlands. The survey probes for a range of topics, including firms' strategy, marketing, human resources management, competition and innovative behavior. We were allowed to add a limited number of questions to explore to what extent Dutch SMEs practice user innovation, and to make a comparison with traditional innovation indicators.

The data collection was done out in May and June 2008, over a period of four weeks, by means of computer assisted telephone interviewing. All respondents were small business owners or general managers. An initial sample of 6 600 firms was drawn from the entire population of SMEs in the Netherlands, as available from the Chambers of Commerce database. Following the Dutch definition of SMEs, only firms with 1-100 employees were sampled. Self-employed individuals without staff were left out of the sample. Responses were obtained from 2 416 persons, a response rate of 37%. In table 1 the distribution of respondents by industries and size classes is presented. A comparison of both distributions that there was no non-response bias present. A χ^2-test indicated no statistically significant differences for industries (p = 0.12) and size classes (p = 0.33).

table 1. Distributions of sample and respondents by industries and size classes

	Sample (n=6 600)	*Respondents (n=2 416)*
Type of industry:		
Farming (NACE codes 1-5)	7%	7%
Manufacturing (NACE 15-37)	24%	23%
Construction (45)	7%	7%
Trade (50-52)	23%	23%
Lodging and meals (55)	4%	3%
Transport (60-63)	8%	8%
Financial services (65-67)	3%	3%
Business services (70-74)	19%	20%
Consumer services (92-93)	5%	6%
	100%	100%
Size class:		
1-9 employees	61%	60%
10-49 employees	33%	34%
50-100 employees	6%	6%
	100%	100%

We stress that the survey was disproportionally stratified in order to compare specific size classes and industries. From table 1 it becomes evident that firms with 1-9 employees make up 60% of the respondents, but in the population of Dutch SMEs this share is 83% (Bangma, 2005). Likewise, for industry types larger shares had been sampled from manufacturing, because this industry receive most attention from policy makers and are 'heavy users' of policy instruments. In our analyses we used a weight variable that was computed with population statistics of the Dutch Chamber of Commerce, representing the actual numbers of firms in combinations of industries and size classes. A remark is that all results and significant differences presented hereafter are robust for either weighing or not weighing the data (i.e. conclusions are identical).

3.2 Indicators

Two basic indicators were formulated to measure user creation and user modification. User creation was introduced to respondents as 'developing entirely new techniques, equipment or software for your own use, because there is no appropriate market supply'.

This introductory sentence was read out loud by the interviewers. Respondents subsequently indicated if they (in the past three years) had realized any such creation. If yes, they gave a detailed description and elaborated on their motives. These questions served to check if reported examples were indeed user innovations, and implicitly, if the dichotomous indicator adequately measures user innovation.

To measure user modification, a similar procedure was employed. First, user modification was defined as 'any modification your firm may do to existing techniques, equipment or software to improve their usefulness to your business. This does NOT include modifications of your own products for customers'. Next, respondents were asked if they had realized any user modification and if yes, open-ended questions were asked to elaborate on the most recent case, and on their motives to innovate.

The survey also measured traditional innovation indicators as defined by the Oslo Manual (OECD, 2005). Following the manual, process innovation was defined as 'the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment or software'. Respondents indicated if they are realized any process innovation in the past three years. If yes, open-ended questions recorded the most recent case, and respondents' motives to innovate. An overview of the various indicators is presented in table 2.

table 2. Indicators

Variable	*Description*	*Values*
User creation:		
Incidence	In the past three years, firm developed new techniques, equipment or software for its own use, because there was no market supply	0 (no) 1 (yes)
Description	Description and motivation for the (most recent) creation	Open-ended questions
User modification:		
Incidence	In the past three years, firm modified existing techniques, equipment of software to make them more suitable for its own specific use	0 (no) 1 (yes)
Description	Description and motivation for the (most recent) modification	Open-ended questions
Process innovation:		
Incidence	Firm implemented a new or significantly improved production or delivery method in the past three years	0 (no) 1 (yes)
Description	Description and motivation for the (most recent) process innovation	Open-ended questions

We note that the current survey was actually our second attempt to measure the incidence of user innovation. In the preceding year (June 2007) we also added indicators to the survey (which is done every year), but these questions did not work out well. We had not instructed the interviewers to explicitly define user innovation to their respondents. Moreover, we had asked respondents only to describe their most recent case, but no to comment on their motives. From a comparison of the open-ended answers and dichotomous responses we learned that a lot of confusion had slipped in. Some respondents mentioned for example new products, or product modifications that were realized to better serve their markets. At least 30 percent of the reported cases were suspicious. Besides, in many cases the reported innovations were described in too general terms, so we could not assess if they were true user innovations. In 2008, we improved our questions and methods by a priori instructing all interviewers to define both types of innovation, and then ask questions later. We also decided to ask for respondents' motives to obtain more elaborated descriptions.

3.3 Results

The analysis started with one of authors of this paper studying all open-ended answers to assess if they seemed true user and process innovations. Some examples of reported innovations are shown in table 3.

table 3. Examples of reported innovations

Type and context	*Description*
User creation:	
Renting of machinery (50 employees)	'We developed an alternative lifting system. We transported our machines with lift trucks, but there were too many accidents.'
Training agency (70 employees)	'We developed software to take exams online, and to present results to individual trainers and customers. Such software needs extreme security features'.
Manufacturer of pulp and paper products (7 employees)	'A wringer device to save money and time. In our business it would be too expensive to order one from a machine builder'.
User modification:	
Manufacturer of shoes (26 employees)	'A CAD CAM system for orthopaedic shoes. I modified existing software for application in my business.'
Manufacturer of textiles (5 employees)	'We modified our wool pressing machine in such a way that it is more efficient in handling small batches'.
Greenhouse firm (11 employees)	'We adapted a sowing machine to better cover specific areas such as corners and borders in our greenhouse'.
Process innovation:	
Water transport firm (75 employees)	'We invested in an automatic washing lane for our ships, to increase their time in service.'
Retail seller of furniture (31 employees)	'We bought a wood-working machine and a bending device, in order to do modifications for our customers ourselves'.
Wholesale firm in food and beverages (7 employees)	'We adopted a new preservation technique based on chilling. It enables us to offer a new freshness concept and to offer a broader range of products'.

In order to filter out falsely identified innovations, we studied all open-ended answers to mark potentially problematic ones. It appeared that for the user creation and modification indicators, 13 and 12 percent of the reported examples were suspicious. Compared to our previous attempt, this result was much better, but admittedly not perfect. We do note that for the process innovation indicator, which was copied from the Oslo Manual, false positives were found as well. This applied to 11 percent of the reported innovations. Some examples:

- manufacturer of diary products: 'We bought a tailor-made device to label our shipments' (no user creation)
- financial services firm: 'We installed new Office software. The old system was no longer compatible' (no user modification)
- agriculture firm: 'My new stable burnt down. I rebuilt it' (no process innovation)

The fact that about 10-15 percent of the identified innovations is suspicious and probably false may be considered worrisome, but we remark that traditional innovation surveys suffer from similar shortcomings (Tether et al., 2002; Teirlinck, 2003; Salazar and Holbrook, 2004). In the following analyses we filtered our data by recoding all suspicious cases into zeros. In doing so the data may be anticipated to adequately reflect the incidence of user innovation.

Incidence of user innovation
Descriptive statistics reveal to what extent Dutch SMEs engaged in user innovation in the past three years. For user creation, four percent of the SMEs developed their own techniques, equipment or software. For user modification, the share of innovating SMEs was 18 percent and substantially larger (table 4).

table 4. User creation and modification by Dutch SMEs (n=2 416)

User creation	*User modification*		*Total*
	no	*yes*	
no	79%	17%	96%
yes	3%	1%	4%
total	82%	18%	100%

Combining the two indicators, 21 percent of the Dutch SMEs can be classified as user innovators. This result is well in the range of the previous empirical studies that were targeted at specific industries and products only, and in line with our first proposition.

Next, table 5 breaks down the incidence of user innovation by industries and size classes. It appears that manufacturing firms are most likely to be user innovators. The share of innovating firms is highest on both the creation and modification indicator, and also on the combined indicator (36 percent). In lodging and meals the share of user innovators is lowest.

table 5. Incidence of user innovation by industry and size classes

	Firms with a user … in the past three years		
	..innovation..	*..creation..*	*..modification..*
Total (n=2 416)	21%	4%	18%
Industry:			
Farming (n=174)	23%	4%	20%
Manufacturing (n=215)	36%	11%	31%
Construction (n=237)	21%	5%	19%
Trade (n=770)	17%	4%	15%
Lodging and meals (n=234)	10%	1%	10%
Transport (n=116)	21%	4%	19%
Financial services (n=67)	19%	5%	17%
Business services (n=446)	25%	6%	21%
Consumer services (n=157)	22%	1%	20%
Oneway F	7.2**	4.9**	5.3**
Multivariate F[b]	3.2*	1.4	2.5^
Size class:			
1-9 employees (n=2008)	18%	3%	16%
10-49 employees (n=364)	35%	9%	30%
50-100 employees (n=44)	37%	12%	32%
Oneway F	31.2**	13.7**	24.1**

Multivariate F[a]	22.9**	5.9*	16.8**

[a] Controlling for type of industry, [b] size classes.
** p < 0.001, * p < 0.01, ^ p < 0.05.

Differences between industries were tested with analysis of variance models. We remark that in manufacturing, firms are on average larger than in services (Bangma, 2005). Significant oneway F-values may therefore be an artifact of size variance. The reported multivariate F-tests control for this potential size effect. In table 5 we find that the shares of user innovators vary significantly across industries[1]. A similar result is found for the user modification indicator.

To explore the differences between manufacturing and services more precisely, contrast tests were done to directly compare manufacturers with services firms[2]. In line with our second proposition, we found highly significant contrasts for user creation ($F = 25.9$, $p < 0.001$), modification ($F = 30.4$, $p < 0.001$) and the combined user innovation indicator ($F = 41.9$, $p < 0.001$).

Our third proposition says that the larger the firm, the more likely that it will engage in user innovation. This supposition is strongly confirmed by our data. As table 5 shows, significant F-tests are found for every indicator, also when we control for industry differences. Contrast tests revealed that in comparison with the smallest firms (with 1-9 employees), larger SMEs are more likely to be user innovators (no output shown here, but available on request).

Comparison with process innovation

To explore the similarities between user and process innovation, table 6 compares the share of innovating firms on both indicators. As we expected, the incidence of process innovation is larger than user innovation (30 versus 21 percent). One remarkable finding is however that the share of user innovators is NOT a subset of the share of process innovators. Our fourth supposition needs to be rejected.

table 6. Process and user innovation by Dutch SMEs (n=2 416)

Process innovation	*User innovation*		*Total*
	no	*yes*	
no	60%	10%	70%
yes	19%	11%	30%
total	79%	21%	100%

It appears that 10 percent of the Dutch SMEs engaged in user innovation, but does not qualify as a process innovator. Despite that process innovation is generously defined, this indicator does not capture all process-related innovative activities by SMEs. User

[1] For convenience and consistency we here report F-tests, despite that most test variables were not normally distributed. The robustness of all presented tests has been checked with non-parametric alternatives (i.e. Mann-Whitney, Kruskal-Wallis and chi-square tests). These tests resulted in similar significances and do not change our conclusions.

[2] Agricultural and construction firms were discarded from these tests, as they are no part of the formal services sector (Bangma, 2005). Their inclusion would however not alter our conclusions.

innovation apparently measures some of the innovation that remains 'hidden' in current public surveys (cf. NESTA, 2007)[3].

In table 7 we further compare user and process innovation by showing industry rankings on both indicators. Both types are obviously correlated, that is, industries will many process innovators are more likely to see user innovation activity going on. Manufacturing and business services rank first and second on both indicators.

table 7. Innovativeness ranking of industries based on process and user innovation

	process innovation	*user innovation*	*ranking of industries*[#]
Total (n=2 416)	30%	21%	
Industry:			
Farming (n=174)	29%	23%	6th → 3rd
Manufacturing (n=215)	45%	36%	1st → 1st
Construction (n=237)	19%	21%	8th → 5th
Trade (n=770)	29%	17%	5th → 8th
Lodging and meals (n=234)	12%	10%	9th → 9th
Transport (n=116)	28%	21%	7th → 6th
Financial services (n=67)	30%	19%	4th → 7th
Business services (n=446)	37%	25%	2nd → 2nd
Consumer services (n=157)	32%	22%	3rd → 4th
Oneway F	11.0**	7.2**	
Multivariate F[b]	8.1**	3.2*	
Size class:			
1-9 employees (n=2008)	26%	18%	3rd → 3rd
10-49 employees (n=364)	48%	35%	2nd → 2nd
50-100 employees (n=44)	53%	37%	1st → 1st
Oneway F	44.1**	31.2**	
Multivariate F[a]	29.2**	22.9**	

[#] Ranking based on process innovation → user innovation
[a] Controlling for type of industry, [b] size classes.
** $p < 0.001$, * $p < 0.01$, ^ $p < 0.05$.

There are also some important differences. If user innovation would be taken as a norm for industry rankings, farming and construction firms would be much more innovative. In the Netherlands these industries are generally considered not be very innovative and in need of improvement, but user innovation indicators reveal that there is more innovation going on in these industries than policy makers are aware of. In construction the frequency of user innovation is even higher than process innovation. As for size classes, no consequences for the innovativeness rankings are found, but we do conclude that the presented results favor our proposition that user innovation indicators give a different view of the innovativeness of firms and industries.

4. Survey of innovations in high-tech SMEs

EIM Business and Policy Research manages a panel of high-technology SMEs in the Netherlands which is surveyed every year. In the winter of 2007, we were able to ask

[3] A follow-up analysis (not reported here) showed that unrecorded innovations could be either user creations or modifications.

detailed questions on the incidence and nature of user innovations in this sample. Transfer to producers was only one of its subjects, i.e. other questions dealt with the roles of external contributors and the amount of money that users spend on their innovations. In this section we give a detailed overview of our findings.

4.1 Sample

The panel of high-technology SMEs was created to explore the nature of high-tech SMEs' business processes, and to assess the effectiveness of innovation and entrepreneurship policies (EIM, 2006). High-tech SMEs are defined as active R&D-performers who purposively develop and/or apply new technologies in their products (Grinstein and Goldman, 2006). They are innovative and process-intensive firms, so we anticipated substantial numbers of user innovators in this sample. Following the Dutch definition of SMEs, the panel contains only independent commercial organizations with 1-100 employees. In terms of revenues and size, high-tech SMEs are slightly bigger than regular SMEs in the Netherlands (EIM, 2006). They are usually operating in manufacturing and knowledge intensive services industries, for example manufacturers of chemicals, rubbers and plastics, machinery and equipment, technical wholesale traders, IT and software developers, engineers and commercial R&D services firms.

Data were collected with computer assisted telephone interviewing. Within a period of four weeks in November and December 2007, surveys were completed with 514 of the 779 panelists (66%). Respondents were basically all directors or managers with a good overview of their firms' practices, including innovation. It appeared that since the start of the panel (in the winter of 2005), 16 respondents had been purchased by larger organizations, or grown in such a way that they did not fit within the panel anymore (i.e. firms with more than 100 employees). These respondents were discarded from further analysis. Our data therefore reflect answers by 498 respondents. In table 8 the sampled firms and respondents are described in terms of industries and size classes. Comparisons of the distributions suggested that non-response bias is not present. Drawing on χ^2-tests we found no significant differences for either industries (p = 0.40) or size classes (p = 0.58).

table 8. Distributions of sampled and responding firms across industries and size classes

	Sample (n=779)	*Respondents (n=498)*
Type of industry:		
Manufacturing		
– Chemicals, rubbers and plastics (NACE codes 23-25)	9%	8%
– Machinery, office-, electrical-, communication-, medical instruments (NACE 29-33)	22%	24%
– Other (NACE 15-22; 26-28; 34-37)	12%	13%
	43%	45%
Services		
– Technical wholesale traders (NACE 51.8)	8%	6%
– IT and telecom (NACE 72; 64.2)	21%	19%
– Engineering and R&D services (NACE 73; 74.2)	23%	25%
– Other (NACE 45, 50-71, 74 excluding 51.8, 64.2 and 74.2)	5%	5%
	57%	55%
	100%	100%

Size class:		
1-9 employees	46%	44%
10-49 employees	40%	41%
50-100 employees	14%	15%
	100%	100%

We stress that our data do not represent the full SME population in the Netherlands. Yet, as the respondents (being panelists) were used to participate in larger surveys, we disposed of a suitable framework for detailed questions on specific user innovations.

4.2 Variables

In order to identify specific user innovations, the survey started with screening questions. First, user creation was explicitly defined by the interviewer, and respondents were then asked if they (in the past three years) had developed any techniques, equipment or software for their own use because there was no market supply. If yes, respondents were asked if any producers had adopted (one of) their innovation(s). In case respondents had created multiple innovations, they were asked to identify their most recent case. This technique implicitly identifies a random sample of research objects of user innovations within firms (Churchill, 1999). An additional advantage is that respondents provide details on recent examples which are still in the top of their minds, and accordingly their answers can regarded as most reliable.

All respondents that passed the screening proceeded with describing the innovation and indicating why they had developed it. Again, these open-ended questions served to check if respondents did not identify false examples, and to assess the quality of our indicators. The survey then continued with detailed questions on the identified innovation, including if producers and other users had somehow contributed to the innovation, how much time and money was spent, and if respondents had applied for IPRs and were willing to freely reveal. In case the innovation had been transferred to producers, we also asked if this was voluntarily.

For user modification the procedure was identical. The interviewers first defined the subject, then asked if respondents had modified any techniques, equipment of software in the past three years, and if yes, if any modification had been adopted by one of more producers. After these screening questions, respondents gave a full description and motivation of their most recent modification, and detailed information on the roles of producers and other users, their expenses, use of IPRs, and – in case there was a transfer to producers – if this had been voluntarily.

In all, the screening was done at the firm level to identify specific user innovations. The screening worked out well, since a sample of 364 user innovations (either creations or modifications) was identified. All subsequent questions were at the level of these specific, randomly identified cases. This was on purpose, as in case of multiple innovations firms are usually not able to provide reliable data on variables such as expenditures, involvement of other parties, transfer to producers, and so on.

As all respondents were participants in a panel that had been surveyed before (EIM, 2006), we enriched our data by merging several background variables including size and industry classifications. The following table 9 summarizes the data that we collected for specific user innovations.

table 9. Data collected for specific user innovations[Ψ]

Variable	*Description*	*Values*
Type	Type of user innovation	1 (creation) 2 (modification)
Description	Description and motivation for (most recent) innovation	Open-ended questions
External involvement:		
Supplier assistance	Firm was supported by producers, for example with information, advice or specific contributions	0 (no) 1 (yes)
User assistance	Firm collaborated with others users, e.g. for information, advice or specific contributions	0 (no) 1 (yes)
Familiar with other users	Firm knows other users realizing similar innovations	0 (no) 1 (yes)
Expenditures:		
Number of contributors	Number of persons contributing to the innovation	Number of involved persons
Time investment	Estimated time invested to develop the innovation (answers given in person-years, -months, -week and/or -days, all recoded in person-days)	Number of person-days
Direct expenses	Estimated financial expenses, other than wages, to develop the application/modification	Amount in €
Total expenses	Estimated total expenses (including wage costs) to develop the application/modification	Amount in €
Appropriation:		
Appropriation behavior	Firm applied for … to appropriate the benefits of the innovation	0 (none) 1 (patent) 2 (trade mark) 3 (copyrights) 4 (trade secret)
Willingness to share:		
Willingness to share	Multiple-item scale of four items ($\alpha = 0.83$): 'Other parties interested in this innovation are welcome to inspect it and imitate it' 'We are willing to share the design of this innovation with others' 'We are willing to actively help others to adopt this innovation' 'We are prepared to share this innovation for free'	1 (definitely not) 2 (probably not) 3 (neither yes or no) 4 (probably yes) 5 (definitely yes)
Transfer to suppliers (only if innovation had been transferred):		
Voluntariness	Firm voluntarily cooperated to transfer the innovation	0 (no) 1 (yes)
Compensation	Firm received … to compensate for transferring the innovation	0 (none/for free) 1 (royalties) 2 (money/discount) 3 (non-financial)
Contact details	Details of (one of) the adopting supplier(s)	Open-ended questions

[Ψ] In the screening part of the survey respondents indicated if they realized any user creations and/or modifications in the past three years, and if these innovations were transferred to producer firms.

4.3 Results

Screening

We found 234 respondents who claimed to be user creators, and 178 respondents indicating to be modifiers. Some illustrative examples of their reported innovations are presented in table 10.

table 10. Examples of reported innovations

Type and context	*Description*
User creation:	
Manufacturer of chemical products (15 employees)	'We built our own vacuum infusion machine by developing software and composing new hardware. Existing machines could be modified, but manufacturers were unfortunately not interested and refused to meet our demands.'
Software developer (20 employees)	'We developed and introduced a software platform where our users can access full details concerning their relationship with us. This tremendously increased the efficiency of our support services.'
Manufacturer of specialty construction materials (35 employees)	'We developed special equipment to fix steel corner profiles to concrete or multiplex surfaces in an ergonomic way. We needed this to make our own products.'
User modification:	
Horticultural R&D services firm (15 employees)	'We raise ornamental plants in hothouses, and different plants require different climates. We adapted our climate control equipment to be able to manage the climates in sections of our hothouses more accurately.'
Medical devices manufacturer (52 employees)	'We modified a polishing machine mainly used in the jewelry industry to polish ear pieces for the hearing aids we produce. We did this to eliminate manual labor and to improve quality.'
Telecom equipment manufacturer (55 employees)	'We use a specific device to test our products. The suppliers software was adapted because it did not meet our requirements.'

The open-ended questions again enabled us to assess if reported innovations were indeed user innovations. Despite that the interviewers had explicitly defined both types of user innovation, some reported innovations were suspicious, for example:

- manufacturer of medical equipment: 'We developed a medical disposable which separates red and white cells from drops of blood within a minute. Drawing on a special technique it determines 15 different facts. We sell this tool to ambulant doctors in developing countries'. (no user creation)
- technical wholesale firm: 'We modified a machine to transport and install tomb-stones in narrow cemetery lanes. Our customers asked for it'. (no user modification)

In order to filter out falsely identified innovations, we studied all open-ended answers to mark potentially problematic ones. We eventually removed all suspicious cases from further analysis: 30 user creations (13 percent) and 18 user modifications (10 percent) were discarded. After this exercise, 364 user innovations remained for further analysis. This finding is comparable with the survey of SMEs as reported in section 3. Although not perfect, the screening questions identify sensible cases.

The incidence of both types of user innovation in our sample of high-tech SMEs is reported in table 11. A number of conclusions can be drawn. As anticipated, we find that many high-tech SMEs are user innovators. Altogether 54 percent of the sample has realized some kind of user innovation in the past three years.

table 11. User creation and modification by Dutch high-tech SMEs (n=498)

User creation	*User modification*	*Total*

	no	*yes*	
no	46%	13%	59%
yes	22%	19%	41%
total	68%	32%	100%

The table also reveals that the share of user creators is larger than the share of modifiers (41 versus 32 percent). This probably because the responding firms are highly innovative and well capable of developing their own techniques, equipment or software. Besides, we stress that the distinction between user-developed applications and modifications is probably blurred. Previous work has shown that even for new creations, innovating actors pragmatically take advantage from existing machines and applications by using their components (von Hippel, 1988; 2005). Both types of user innovation probably represent extremes of a continuum, rather than clearly distinguished artifacts.

More details on the incidence of user innovation in Dutch high-tech SMEs is given in table 12. The table compares the shares of user innovators (combined indicator), creators and modifiers in various industry and size classes.

table 12. Incidence of user innovation in high-tech SMEs, by industry and size classes

	Firms with a user … in the past three years		
	…innovation…	*…creation…*	*…modification…*
Total (n=498)	54%	41%	32%
Industry:			
Manufacturing (n=226)	62%	47%	39%
Services (n=272)	48%	36%	26%
Oneway F	10.5*	5.6^	9.7*
Multivariate F[b]	6.3^	3.7^	5.4^
Size class:			
1-9 employees (n=218)	43%	34%	21%
10-49 employees (n=205)	60%	44%	37%
50-100 employees (n=75)	71%	51%	51%
Oneway F	11.0**	3.9^	13.8**
Multivariate F[a]	8.9**	3.4^	11.2**

[a] Controlling for type of industry, [b] size classes.
** $p < 0.001$, * $p < 0.01$, ^ $p < 0.05$.

Echoing our findings in section 3, we find that manufacturers are more likely to be user innovators. The same applies to larger SMEs. Drawing on analysis of variance tests[4] these differences are significant, also when we control for size and industry variation.

External involvement

For the 364 identified user innovations follow-up questions were asked on the involvement of external parties. Respondents indicated if they had been supported by producers, for example with information, advice or specific contributions. They also indicated if they knew other users who developed similar innovations, and if they had cooperated with other users to develop their innovations. These kinds of external involvement were reported by 41, 24 and 39 percent of the respondents, respectively. These shares are slightly higher than innovation collaboration by producer firms.

[4] Again, our findings are robust for the choice of test, i.e. non-parametric tests give similar outcomes.

Statistics Netherlands (2006) for example demonstrated that 28 percent of the Dutch innovating businesses develop innovations in cooperation with suppliers, and 12 percent with competitors, i.e. other firms at the same horizontal level (p. 113-114). User innovation can well be a collaborative effort and external involvement is at least as likely as with producer innovation.

table 13. External involvement in user innovations of high-tech SMEs

	Producer assistance	*User assistance*	*Familiar with other users*
Total (n=364)	41%	24%	39%
Type:			
User creation (n=204)	42%	29%	46%
User modification (n=160)	40%	18%	30%
Oneway F	0.1	6.5^	8.6*
Multivariate F[bc]	0.2	5.2^	7.0*
Industry:			
Manufacturing (n=195)	42%	15%	28%
Services (n=169)	41%	35%	52%
Oneway F	0.1	22.4**	21.3**
Multivariate F[ac]	0.0	17.7**	17.8**
Size class:			
1-9 employees (n=121)	36%	32%	47%
10-49 employees (n=167)	40%	22%	36%
50-100 employees (n=76)	51%	16%	34%
Oneway F	2.5	4.0^	2.3
Multivariate F[ab]	2.4	1.8	0.6

[a] Controlling for type of user innovation, [b] type of industry, [c] size classes.
** p < 0.001, * p < 0.01, ^ p < 0.05.

We also compared the incidence of supplier and other users' involvement between types of user innovation and industrial and size classes (table 13). For producer assistance, no differences were found, but for the roles of users we found some significant results. User creations are more likely to be developed with the help of other users (29% versus 18%). When controlling for industry and size variation, this difference is still significant (multivariate $F = 5.2$, $p < 0.05$). Since it concerns new techniques, equipment or software which does not exist yet, current supplies are probably not available. In cases of user creation respondents are also more likely to be familiar with other users developing similar innovations (46% versus 30%). For type of industry, high-tech services SMEs are more likely to cooperate with other users than in manufacturing (35% versus 15%). They also happen to know other users with similar innovations more often (52% versus 28%). These results are consistent with the innovation literature that stresses that the production and delivery processes of services are characterized by frequent interactions with the external environment, including users. Besides, services firms also contain IT developers contributing to open source software communities (the kind of innovation marked by intensive user collaborations by definition).

Expenses

Four indicators were applied to measure how much users had spent on their innovations: number of persons contributing to the innovation, time investment in person-days, direct expenditures other than wage costs (in €), and total expenses including both wages and other costs (in €). These figures are obviously indicative only since they reflect a posteriori estimates of respondents. See table 14.

table 14. Expenses on user innovations in high-tech SMEs (n=364)

	Number of contributors	*Time (person-days)*	*Direct expenses (*€ 1 000)*	*Total expenses (*€ 1 000)*
Mean	3.0	196	51.1	184.4
Minimum	1	1	0	1
1st Quartile	2	15	0	9
Median	3	61	5	30
3rd Quartile	4	183	40	150
Maximum	10	1 826	1 000	2 500

We conclude that user innovations are certainly not trivial. Time investment is on average 196 person-days, with out-of-pocket costs exceed € 50 000. It also appears that expenses on user innovation are very diverse. In terms of numbers of involved persons, user innovations see on average 3.0 contributors, but their number ranges from one to ten in our sample. For time investment the number of person-days varies from one (a simple modification in a software program) up to 1 826 (i.e. five person-years spent on a diagnosis instrument for stem cell research). Direct expenses went up to € one million, and estimated total expenses could be € 2.5 million.

In table 15 we compare the expenses on various background variables. The differences between user creations and modifications are evident. Direct and total expenses on user creations are approximately twice as high. Drawing on analysis of variance these differences are consistently significant, also when we control for industrial and size variation.

table 15. Expenses on user innovations in high-tech SMEs (continued)

	Number of contributors	*Time investment (person-days)*	*Direct expenses (*€ 1 000)*	*Total expenses (*€ 1 000)*
Total (n=364)	3.0	196	51.1	184.4
Type:				
User creation (n=204)	3.2	282	64.4	235.0
User modification (n=160)	2.7	86	34.1	119.8
Oneway F	7.8*	31.5**	4.6^	6.8*
Multivariate F[bc]	11.4*	30.9**	5.1^	6.1^
Industry:				
Manufacturing (n=195)	3.1	181	60.5	194.6
Services (n=169)	2.9	215	40.2	172.5
Oneway F	0.7	0.9	2.1	0.4
Multivariate F[ac]	0.1	0.7	1.8	0.4
Size class:				
1-9 employees (n=121)	2.3	205	42.5	176.8
10-49 employees (n=167)	3.2	193	45.1	177.7
50-100 employees (n=76)	3.6	191	78.1	211.3
Oneway F	17.6**	0.0	1.7	0.2
Multivariate F[ab]	20.7**	0.0	1.7	0.3

[a] Controlling for type of user innovation, [b] type of industry, [c] size classes.
** p < 0.001, * p < 0.01, ^ p < 0.05.

For industries, the results in table 15 suggest that user innovations in services are on average more time-demanding (215 versus 181 days) while in manufacturing they require more capital investments (€ 60 500 versus € 40 200). Estimated total expenses of manufacturers also defeat those of services firms (€ 194 600 versus € 172 500). From a theoretical perspective these numbers are comprehensible. As mentioned, previous studies have repeatedly mentioned that innovations in services are labor-intensive and require less financial investments. However, none of the differences is significant. As the variance on all indicators is substantial, we cannot draw conclusions on significant differences here. The comparison between size classes clearly shows a correlation between firm size and the number of persons contributing to user innovations. For the other indicators, descriptive statistics suggest that the largest SMEs (50-100 employees) engage in user innovation with more out-of-pocket and total costs, but again, the differences are not significant.

Appropriation

The survey revealed that only 13 percent of all user innovations is somehow protected. Patenting is the main protection mechanism, i.e. 10 percent of the sampled user innovations is patented, while only one percent is patronized with trade marks and two percent with explicit secrecy attempts. The application of copyrights was done in only 0.3 percent of the cases. This confirms our sixth proposition that user innovators generally refrain from using intellectual property rights.

In table 16 we analyze the incidence of appropriation between groups of respondents. It is confirmed that user creations are protected more often than modifications, also when we control for industry and size differences ($F = 8.5$, $p < 0.01$). This result reflects that innovations which are developed from scratch are more likely to contain genuinely new elements which are suitable for patenting or others forms of protection. Another reason may be that new creations demand about twice as much resources (see table 15). Higher costs might induce firms to ponder on how to earn back their expenses.

table 16. Appropriation of user innovations by high-tech SMEs

	Share protected by IPRs
Total (n=364)	13%
Type:	
User creation (n=204)	17%
User modification (n=160)	6%
Oneway F	10.4*
Multivariate F^{bc}	8.5*
Industry:	
Manufacturing (n=195)	9%
Services (n=169)	16%
Oneway F	4.7^
Multivariate F^{ac}	3.0
Size class:	
1-9 employees (n=121)	18%
10-49 employees (n=167)	11%
50-100 employees (n=76)	7%
Oneway F	2.8

	Share protected by IPRs
Multivariate F[ab]	1.3

[a] Controlling for type of user innovation, [b] type of industry, [c] size classes.
** $p < 0.001$, * $p < 0.01$, ^ $p < 0.05$.

For industries the table suggests that services firms are more inclined to apply for IPRs than manufacturers (16 versus 9 percent). Oneway analysis of variance reveals a significant difference, but after controlling for type of innovation and size variance, the significance vanishes. A follow-up analysis (not presented here) showed that the higher incidence must be attributed to commercial R&D laboratories, a subgroup within the sample of high-tech services SMEs. These firms frequently apply for IPRs, i.e. 30% of their user innovations was patented. After excluding commercial R&D laboratories the oneway F-test became insignificant too. For size classes, no significant differences could be established as well.

Willingness to share and transfer to producers

The survey extensively probed for respondents' willingness to share their innovations, and also measured if there was an actual transfer of user innovations to producer firms. Being a latent construct, willingness to share was measured with a multiple-item scale of four items. Its items are presented in table 9. Respondents were invited to complete these items on five-point scales (definitely not-probably not-neither yes or no-probably yes-definitely yes). The scale had satisfying psychometric properties, i.e. Cronbach's Alpha = 0.83, average inter-item correlation = 0.55, item-rest correlations ≥ 0.56, all indicating good internal consistency (Hair, Anderson, Tatham and Black, 1998). Exploratory factor analysis revealed only one factor with an eigenvalue exceeding one and explaining 67% of the variance, indicating one-dimensionality.

The mean score of the four-item scale was 2.35. For the 364 sampled innovations, in 113 cases its developers were most reluctant to share (answering 'definitely not' on all four items), while in 18 cases they were most willing to share (answering 'definitely yes' on all items). When we regard average scores lower than 3.00 as being on the negative side of our scale, a majority of 66 percent tends to be unwilling to share. In contradiction, 28 percent of the respondents had average score > 3, indicating they were willing to share their innovations.

We stress that the items were formulated rather extreme. They focus on respondents' willingness to freely reveal their innovations by voluntary giving up all existing and potential intellectual property rights and giving access to all interested parties, without direct payment or other compensation, so that the innovation in essence becomes a public good (cf. Harhoff et al., 2003). The scale does not indicate users' willingness to *trade* their innovations and, more importantly, to share with a limited number of others rather than with everyone. In fact, interviewers who implemented the survey informed us that some respondents had proactively mentioned that their answers would be different in case of 'selective revealing'. They were willing to reveal, but only to friends and well-known network partners (strong ties), and to other users without commercial interests.

As for the transfer of user innovations to producers, it appeared that 25 percent of all identified user innovations had been transferred to producer firms, that is, users could mention producers that adopted their innovations. Subsequent questions recorded if the transfer had been voluntary, and if firms had received some kind of compensation. We found that 87 percent of the transferred user innovations were passed on voluntary while only 13 percent was adopted in a 'hostile' manner. Moreover, 48 percent of the transferred innovations was given away for free, while 39 percent was compensated in an informal manner, for example by means of promises on future reductions, free advice or temporary staffing services. Only 13 percent of the transferred user innovations were compensated with royalty agreements.

In table 17 we compare respondents' willingness to share, and the incidence of transfer to producers, between types of user innovations, industries and size classes.

table 17. Willingness to share and transfer of user innovations by high-tech SMEs

	Willingness to share (scale 1-5)	*Transfer to suppliers*
Total (n=364)	2.35	25%
Type:		
User-developed application (n=204)	2.28	25%
User modification (n=160)	2.43	25%
Oneway F	1.1	0.0
Multivariate F[bc]	1.5	0.0
Industry:		
Manufacturing (n=195)	2.16	19%
Services (n=169)	2.59	31%
Oneway F	10.3*	7.0*
Multivariate F[ac]	10.2*	6.6^
Size class:		
1-9 employees (n=121)	2.37	26%
10-49 employees (n=167)	2.34	25%
50-100 employees (n=76)	2.32	22%
Oneway F	0.0	0.1
Multivariate F[ab]	0.0	0.2

[a] Controlling for type of user innovation, [b] type of industry, [c] size classes.
** p < 0.001, * p < 0.01, ^ p < 0.05.

We find no significant differences between creations and modifications. Given that user creations are more costly in terms of time and money, this may be surprising, but apparently users have good reasons to reveal their innovations (also see our discussion in section 2.3). For industries, table 17 shows that services firms are more willing to reveal their user innovations, and more likely to see their innovations adopted by producers. This confirms our eighth proposition on industry differences. For size classes, no significant differences are found, implying that our ninth proposition is not supported by the data.

Supplier follow-up

In case of transfers to producers, respondents were kindly asked for details of those producers. Out of the 90 relevant respondents, 28 were cooperative on this question. We randomly contacted five producers by telephone to ask how the innovation was transferred, if there had been any compensation, if they had conducted follow-up development activities, and if yes, how much they had spent on these activities. Five cases are clearly not sufficient for statistical inferences, but they are illustrative and shed a light on what happens at the producer side when user innovations are adopted. We now elaborate on the five cases:

- User A is a developer and producer of specialty foods for allergic patients. The enterprise modified a machine to better process raw vegetables by developing a new input chamber (a covered metal box with a hole in bottom from which vegetables flow into the processing machinery). User A regularly processes carrots, and found that his current input chamber resulted in too much breakage. It took 25 person-days and € 15 000 out-of-pocket costs. Supplier A, a machine manufacturer for the food industry and close friend of the user, was allowed to copy the innovation for free. He further developed the dosing box into a new line of add-on boxes to his current machines, to better account for specific shapes of input materials. At the time of our phone call, the manufacturer had invested about € 100 000 in further development.
- User B is a engineering firm specialized in complex renovation and restoration projects. One of its services applies 3D measurement instruments to design and produce tailor-made components such as leaded stained glass window segments or parts to repair damaged statues. The innovation was a software tool to automatically process 3D measurement data into digital templates to control a (milling) machine. The software tool was programmed by three employees in an estimated 120 person-days. To integrate the application with current CAD/CAM software, user B also recruited external programmers (at the expense of € 75 000) from supplier B, a producer of CAD/CAM software. They adopted the tool in their own software products. Additional expenses by supplier B were limited to an estimated 20 person-days. User A is now compensated for its efforts by an informal royalty agreement.
- User C is a manufacturer of bakery products for the health sector (hospitals, care centers). Its new head of production – a former machine constructor - was dissatisfied with his current sugar melting machine. To reduce downtime caused by sugars re-crystalizing he ordered a new melting machine and modified it with new blades, increased mechanical power, and smooth coatings in some key pipe parts. He spent an estimated € 200 000 on wage costs and deliveries of new parts. The innovation was adopted by supplier C, a wholesale trader in machines and equipment, who delivered the new sugar melting machine. Supplier C did not conduct any follow-up research or development activities, but rather benefited from similar customizations in two follow-up deliveries of sugar melting machines (with average customization costs of about € 100 000 each).
- User D is a horticulture enterprise specialized in improving orchids. Its director was dissatisfied with his internal transport system in which a robot transports trays of orchids. By modifying the robot's arms its accuracy was significantly improved, also enabling in a higher density of plants per square meter. The modification took an estimated 60 person-days and additional expenses of € 2 000. Supplier D is an engineering firm of greenhouse constructions, instruments and machines. It copied the improved robot arm for free 'without much additional investment'. The new robot arm is now part of all internal transport systems which are delivered to greenhouse enterprises.
- User E is a food and nutrition engineer of Turkish origin, developing new yogurts, cheeses and beverages. The innovation relates to the modification of a filling machine. The filling head was modified, and the cover closing improved so that air

was more effectively excluded from the product, thus reducing spoilage due to formation of mold. The innovation was realized in 20 days and out-of-pocket expenses of € 15 000. Supplier E, a trader and producer of agricultural machines met user E at a trade conference. He was allowed to inspect the modification and to copy it. There was no explicit compensation, except a promise that user E would be generously treated in case of future orders from supplier E. The supplier adopted the improved cover closing mechanisms in some of its own machines. There was about € 10 000 spent on additional development activities.

In table 18 we summarize relevant details of the five cases.

table 18. Estimated user and producer expenses[a] and forms of compensation in five cases

Case	*User expenses*	*Producer expenses*	*Compensation*
A	25 days + € 15 000	€ 100 000 (total expenses)	None
B	120 days + € 75 000	20 days + € 0	Royalty agreement
C	€ 200 000 (total expenses)	0 days + € 0[b]	None
D	60 days + € 2 000	minimal	None
E	20 days + € 15 000	€ 10 000 (total expenses)	Reduction on future orders

[a] Time investment (in days) and direct expenses (excl wage costs) unless otherwise mentioned.
[b] Excluding average customization costs of € 100 000 in two follow-up projects.

Statistical inferences are not possible, but some tentative conclusions may be drawn for future research. It seems that users spent more on developing their innovations than producers spent on converting their innovations into commercial offerings. With the exception of case A, all users invested more to develop their innovation than the adopting producers did[5]. Secondly, the cases suggest that user innovators are most willing to selectively reveal their innovations to others, i.e. to close friends and other strong ties in their network, and that formal compensation arrangements are very scarce. In case E, there was the rather vague promise of future price reductions, while only in case B compensation was explicitly agreed upon. The royalty agreement however was also informal, i.e. no explicit contract was signed, the agreement rather drew on good faith. In the next section we will further discuss our suggestions for future research.

5. Discussion

In the introduction section of this paper we discussed three objectives, and we here present our conclusions accordingly. Next, we elaborate on the implications and limitations of the study.

[5] One could for example convert person-days into euros by estimating their wage costs. The average daily fee of a Dutch process engineer with 15 years of tenure is for example € 250, see www.intermediair.nl/salariskompas). One may also include overhead costs which would result in much higher daily fees. Whatever rule-of-thumb, in cases B-E users spent more on development than their corresponding producers.

5.1 Conclusions

Drawing on a broad and representative sample of 2 416 SMEs in the Netherlands, we found that many firms are user innovators. In the past three years, four percent of the Dutch SMEs created new techniques, equipment or software because there was no market supply, and 18 percent modified such objects to better satisfy their process-related needs. Overall, roughly one out of five firms in the SME population may be considered user innovators. This result is fairly important as it demonstrates that user innovation is present in basically all industries, and not in just the specific products and industries that have been investigated so far. We also find that manufacturers and larger SMEs, being more process-intensive and accordingly having more opportunities to recognize process-related needs, are more likely to be user innovators than services firms and smaller SMEs, respectively. Nevertheless, the incidence of user innovation is still rather substantial even among these latter types of SMEs. One of our findings was that the hotels and restaurants are least likely to engage in user innovation, but still ten percent of these SMEs qualify. Likewise, for firms with less than ten employees we find that still 18 percent realized at least one user innovation in the past three years.

A second and important finding is that current innovation surveys, in particular the publicly funded Community Innovation Surveys (CIS), do not to sufficiently capture user innovation. More specifically, ten percent of the Dutch SMEs are found to be user innovators, but they are not recorded to be process innovators. This finding was in contradiction with to our presuppositions, i.e. the process innovation indicator is broadly defined, and we expected that the share of user innovators would be a subset. We also found that user innovation indicators change our view of the innovativeness of industries. Dutch industries such as farming and construction - which are traditionally regarded not to be innovative – rise on the innovativeness ranking when user innovation is taken into account. In construction, the share of user innovators is even higher than the share of process innovators. This again demonstrates that user innovation is part of the innovative activity that remains hidden in traditional surveys.

As for the transfer of user innovations, we found that users barely protect their innovations with intellectual property rights. Only 13 percent of the innovations is protected, with patents being the dominant type. Our results suggest that there is a feedstock of innovation activities from users to producer firms, and this transfer is mostly voluntary. In the context of high-tech SMEs, producers appear to benefit directly from at least one quarter of users' innovations. We remark that our survey mainly revealed voluntary knowledge spillovers, and that users will frequently overlook involuntary adoptions by producers. Knowledge related to user innovations will also spillover in traditional ways, for example due to labor mobility or site visits of producers (Griliches, 1992). Although traditional spillovers have not been studied here, they are likely to apply as well.

5.2 Implications and limitations

Our findings have implications for three audiences: people in statistical offices, policy makers and researchers. To those involved in the development and implementation of public innovation surveys, we recommend that future surveys should explicitly capture user innovation. Given that a significant amount of firms practices user innovation, and that the current process innovation indicator fails to record this innovative activity, we think it is justified to modify the CIS surveys in such a way that creations and modifications of techniques, equipment and software are explicitly measured. This will provide a more complete picture of the process-related innovative activities of firms. In the short run we would recommend to pilot our new indicators in a limited number of countries. This will clarify if these indicators provide sensible data when they are part of postal surveys. In the longer run, we propose that the next version of Oslo Manual should be refined as far as the measurement of process innovation is concerned. After doing so, the section on process innovation will more precisely measure firms' process-related innovative efforts, and reveal part of the 'hidden' innovative activity that traditional innovation metrics overlook (NESTA, 2006; Laestadius, 1998).

As for policy makers, we pose that the mix of innovation policies could better reflect the principles of user innovation. We found that many user innovations spill over to producer firms, suggesting that there is a significant feedstock of innovation activities from user to producer firms. We also remark that previous work has demonstrated that users tend to develop innovations which are much more radical than producer innovations, and that these innovations often induce completely new products and industries. These are common arguments in favor of policy interventions, because the social benefits of user innovation clearly exceed the benefits of individual users. The explicit measurement of user innovation in publicly funded surveys would provide policy makers with a better view on the innovativeness of firms and industries, and may be helpful to direct their efforts. In addition, we plea to explore if and how current policies should be refined (also see hereafter). As mentioned in the introduction section, current policy mixes in basically all countries do not account for user innovation but rather focus on producers. We recommend that policies must at least not favor producers at the expense of user innovators. In this context, one important finding is that users do not care about intellectual property rights very much. This sheds a new light on the importance of patents and other IPRs to stimulate innovation.

Our surveys demonstrated that it is well possible to collect relevant information from broad samples of users, either at the firm level and the level of specific creations and modifications by users. For future application, some issues to keep in mind would be the following. We learned that both types of user innovation need to explicitly introduced to respondents to reduce misinterpretation. Each indicator should also be followed up with open-ended questions to check if reported cases are indeed user innovations. Moreover, we recommend to draw on survey techniques which enable the researchers to clarify their questions. It takes experienced interviewers in order to adequately collect data. Even with this extensive approach, one should still anticipate that respondents may report false examples. In our samples we found 10 to 15 percent of all reported innovations to be suspicious. Although a nuance is that for the traditional process innovation indicator the share of false positives was barely lower, we do think there are opportunities for improvement. For future research we recommend to test alternative indicators and to organize new experiments. Potential avenues would be to develop indicators for specific industries, or to ask questions on various objects of innovation such as user innovations in software and hardware products, respectively. Such methods might provide a more precise picture with less suspicious cases.

Our study had some limitations that provide challenges for future research. Firstly, we stress that user innovations can also be developed by consumers. Empirical evidence has so far shown that consumers may innovate too, for example in extreme sports equipment (Franke and Shah, 2003). Future research should explore the incidence of user innovation in broad samples of citizens to assess the incidence of this phenomenon, which may be more important than innovation by firms. Another limitation was that we studied the transfer of user innovations only in the context of high-tech SMEs. Although we see no obvious reasons why our findings would not generalize, these respondents do not represent the larger population of SMEs. One might only guess how much user innovations are transferred to producers in such broader samples. Nevertheless, high-tech SMEs are the most important target of current innovation policies, and our finding of free and voluntary knowledge spillovers certainly informs the debate on future innovation policymaking. In order to justify policy interventions however, the mere existence of spillovers is not enough. We also need to know to what extent user innovation is hampered by market and/or system failures, before we can safely conclude that there governments should proactively intervene on user innovation. This is a line of research that we intend to develop in the near future.

Finally, our study resulted in some interesting findings which call for more. From our data and feedback of the interviewers, we got the impression that many users are inclined to reveal their innovations selectively, that is, to a limited number of close friends and other strong ties in their networks. So far, the literature on sharing has mainly focused on the opposites of full appropriation versus free revealing. The issue of selective revealing brings another dimension to this discussion. Another tentative finding is that for a limited number of user innovations we managed to trace and question the adopting producers, and found that users seemed to spent more on developing their innovations than producers did on converting their innovations into commercial offerings. A challenge for future work is to find pairs of users and producers which will allow for statistical inferences, and study the flow of knowledge to producers in more much detail.

In the future of business, user innovation will probably be even more important than it is today. Empowered by the internet, specific types of user innovation, i.e. open-source software development and distributed innovation, will be increasingly seen. We therefore strongly appeal to statisticians, policy makers and researchers to explore the implications of user innovation for the current innovation metrics and policies, respectively.

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