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NESTA Making Innovation Flourish

Measuring user innovation in the UK

The importance of product creation by users

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Foreword

There is a growing belief that the traditional division of labour between innovators and customers has started to break down. Two developments are driving this shift: markets are becoming more diverse and user needs more varied, while sophisticated, cheap tools for innovation are becoming widely available to both corporate customers and individual consumers. The Internet in particular is enabling innovative users to come together in communities that develop innovations that in some cases compete with, and in others complement, those produced by specialists.

This democratisation of innovation has potentially critical implications for innovation policy, which has often focused on the activities and motivations of specialist producers. This makes it vitally important to establish how much user innovation goes on, and its economic significance. Most studies of user innovation to date, especially in the UK have focused on specific industrial sectors, product groups or communities of users, and have shied away from attempting to measure how much user innovation actually occurs.

The large scale surveys presented in this report set out to address the gap in the evidence by identifying the scale and importance of user innovation by consumers and businesses across the UK economy.

In doing so, this report constitutes a first step towards a better understanding of this phenomenon, and the formulation of policies to support it.

As ever, we look forward to your comments.

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Executive Director of Policy and Research, NESTA

April, 2010

NESTA is the National Endowment for Science, Technology and the Arts.

Our aim is to transform the UK's capacity for innovation. We invest in early-stage companies, inform innovation policy and encourage a culture that helps innovation to flourish.

Executive summary

Measuring user innovation

Innovation activities have been traditionally considered the domain of specialist producers who design, develop and commercialise new technologies that are then passively adopted by users. This producer-centred model, inspired by the pioneering work of Austrian economist Joseph Schumpeter, is linked to a specific set of policies to encourage innovation through the use of intellectual property rights and government subsidies for these producers.

However, there is a growing body of research showing that users – both firms and individual consumers – play a much more active role in processes of innovation than it had been generally believed. Users create and modify products and services to serve their own needs, and often make these innovations freely available to each other, as well as producers. Many successful products in the market were initially developed by users, and eventually adopted and commercialised by producers.

This suggests a shift in the locus of innovation in advanced economies such as the UK: technology and market trends are changing the way innovation gets done, and by whom. For example, as design and communication costs decline due to rapid improvements in computer-based design tools and Internet technologies, user and open collaborative innovation models are beginning to complement, and in some cases supplant, traditional, producer-centred innovation processes over a steadily wider range of conditions. These findings and trends represent fundamental challenges to producer-centered models of innovation and to policies – including the current intellectual property rights framework – that are related to that model.

To date, most studies of user innovation have focused on specific consumer and industrial categories. But cross-industry studies of the phenomenon are needed to build a robust evidence base for policymaking, and to support managerial decision-making.

This report sets out to address this gap in the understanding of the role of users – including individual consumers and business firms – in processes of innovation across a range of sectors. It presents findings from a world-first survey of product innovation by consumers, and from the first cross-industry survey of user process innovation by UK firms.

Main findings of the consumer level survey

There is a simple reason why there have been, to date, no surveys of product innovation by individual end consumers – the general assumption has been that they don't engage in it. This explains the absence of indicators of consumer innovation from official surveys. Yet, empirical studies of specific fields have shown that a great deal of innovation is in fact carried out by individual users of both physical consumer products and information products, such as personal software.

Two consumer surveys have been undertaken to explore the importance of consumer-level innovation, that is, instances where individuals improve the products they use in their everyday lives, or create new ones. The first survey is a broad omnibus targeting a representative sample of 2,019 consumers older than 15. The second is a more in-depth survey of 300 consumers.

Findings from the omnibus survey, conservatively adjusted for false positives, show that 8 per cent of UK consumers create or modify one or more of the consumer products they use in order to better address their needs.

Almost half of these innovators, 3.4 per cent, report that their new or modified products are, as far as they are aware, original innovations. Approximately 2 per cent report that their user innovations have been taken up by other users, or even adopted and manufactured commercially by producers. Creation and modification of physical products by individual consumers is about three times more frequent than creation or modification of software for personal use.

Innovative consumers are more frequently male, young, employed, and with high levels of educational attainment. Cars, sporting equipment and tools such as those used in the workshop and for gardening are some of the physical products that are more often subject to user innovation by individual consumers.

Specific examples from the consumer innovation survey include the case of one consumer who developed a software program enabling him to catalogue the 4,000 CDs in his collection in far more detail than it is possible with commercially-available systems. Another respondent built an automatic feeder for his diabetic dog, using parts from a washing machine and a household timer, in order to provide medically prescribed regular and precise feedings.

Main findings of the firm level survey

Firms use process technologies, such as machinery or software, to produce goods and services. For example, a robot that stamps out metal parts is a process machine, and the software controlling that robot is process software. The effectiveness of these process technologies impacts on business productivity, and competitiveness.

The firm-level survey underpinning the second part of this report explores the extent to which UK firms develop and improve process technologies to better serve their in-house needs. The survey also explores the diffusion of these improvements and innovations from user firms to specialist producers of process technologies. The firm-level survey collected data from 1,004 firms between ten and 250 employees in 15 industrial sectors through a telephone survey.

The results of the survey show that 15 per cent of respondents – a substantial share of the sample – have modified or created process equipment and/or process software for their own use over the last three years. Larger firms have been found to engage in user innovation activities more frequently than smaller ones.

User innovation varies widely across sectors. Software and IT, Mining and Quarrying, Other Manufacturing, Other Creative Activities, and Aerospace and Automotive show particularly high levels of user innovation.

Specific instances of user innovations from the firm survey include a firm that developed its own machine to produce the contact lenses it sells in the market. A manufacturer modified the laser-guided vehicles in its production plant to enable them to pick up paint and automatically deliver it. A farm modified the peeling and produce washing machines it uses in order to better suit them to its production needs.

The survey has identified remarkable levels of diffusion of user innovations between user firms, and from user firms to specialist suppliers of process technologies. Twenty-five per cent of user-innovator firms report that they have shared their process innovations with equipment suppliers and with other users, half of the times without charging the recipients. Only in a fifth of the reported instances of sharing did user-innovator firms receive royalties or some other compensation for their innovations. This is in line with the results of previous surveys of user innovation at the firm level undertaken in Canada and the Netherlands.

Implications of the consumer level survey

The survey findings document the widespread creation and modification of consumer products by consumers themselves independent of producer involvement. Innovation by users as documented in the survey is not the same as 'co-creation' processes in which consumers and producers work together to develop a product. Nor is it a form of 'user-driven' innovation, in which producers pay close attention to user needs while developing new products for consumers. What has been documented in this survey is something quite different: widespread development and modification of consumer products by users without producer involvement.

The survey of consumer innovation demonstrates the importance of this phenomenon. Significant numbers of individual consumers are deploying sophisticated skills-sets to create and modify products they use in their everyday lives. Extrapolating the 8 per cent of individual consumers active in user innovation according to the survey to the UK population aged over 15 suggests that there are potentially over three million people engaged in these activities. This number is orders of magnitude higher than the number of professional consumer product designers and developers employed in the UK.

The sheer magnitude of product development activities by consumers, together with findings from earlier research documenting the frequency with which commercially successful consumer products have in fact originated from users, suggests that this phenomenon could have large social and economic impacts.

The results of the survey show that consumers often freely share their innovations with others instead of patenting or otherwise protecting them. This is a potential source of major 'information spillovers' with beneficial impacts on social welfare that should be encouraged by policymakers.

Consumers frequently modify existing commercial products in order to create their innovations. Policymakers should take this into account when putting in place policies that might, intentionally or by neglect, hinder consumers' freedom to tinker with and modify the products they buy.

Finally, it is crucial to ensure that official innovation indicators and future surveys of innovation in the UK include innovation by consumers. These activities appear to be a major category of undocumented innovation in the UK. Better understanding of their prevalence and impacts will help to formulate more effective innovation policies, as well as business strategies for the management of innovation.

Implications of the firm-level survey

The results of the survey shows that specialist producers often adopt and commercialise innovations initially developed by user firms. This indicates that user firms can be a source of process technology innovations that are valuable for large populations of users – these innovations are not simply special adaptations of technology to local conditions. The significant rates of innovation diffusion from users to producers identified in the survey are in line with the findings of sector-specific historical studies, and have potentially important implications for innovation policy.

For example, although the results of the survey show that many user innovators do transfer their innovations to producers, it is also true that many user innovations seem to be 'kept under wraps' by the firms that have developed them. Some of these innovations might not be applicable elsewhere, or may give their developers a competitive advantage that they are understandably unwilling to share with others.

But it is also possible that some user innovations that could be transferred to other firms without harming their developers' competitiveness do not see the light of day because their developers are unaware of their applicability elsewhere, or lack the incentives to share them more broadly. If user-innovator firms expect to gain little reward from transfer, they may have correspondingly low incentives to actively seek out transferees. This coordination problem could justify the formulation of policies to encourage firms to assess the wider applicability of their user innovations, and when it makes sense, share them with others.

Contents

Part 1: Introduction

This report maps, for the first time, the user innovation activities of UK firms and consumers

It has long been established that users are an important source of valuable ideas for innovative firms, and that sophisticated users may 'pull', through their demand, innovation from producers.[1] But users also engage in highly innovative activities of their own accord in fields as diverse as software[2] medical instruments[3] or sporting equipment.[4] A growing body of literature has shown that these user innovators modify existing products and services, or even create entirely new ones from scratch, without any involvement from producers of goods and services.[5]

Until now, there has been no comprehensive account of the importance of user innovation in the UK. This report sets out to address this important gap in the evidence base. It breaks new ground by exploring the innovative activities of UK consumers in an experimental survey that is the first of its kind in the world. It also provides a set of indicators and metrics for user innovation at the firm level drawing on the first survey of user innovation by UK firms.

Report outline

Part 1 of the report introduces the concept of user innovation by firms and consumers, presenting some examples of the phenomenon. It also highlights current initiatives to measure user innovation activities that have until now remained 'hidden' from policymakers.

Part 2 describes the methodology and findings of the survey of innovation among UK consumers.

Part 3 describes the methodology and findings of the survey of user innovation by UK firms.

Part 4 presents the implications of the report.

Appendix 1 contains an in-depth review of the academic literature on user innovation.

Appendix 2 contains a detailed description of the methodologies of the surveys.

1. For example, see Gardiner, P. Rothwell, R. (1985) Tough Customers: Good Designs. 'Design Studies'. Vol. 6, No. 1 pp.7-17; Rothwell, R. Freeman, C., Jervis, P., Horsley, A., Roberston, A.B., Townsend, J., (1974) 'SAPPHO-Updated; Project SAPPHO Phase II'. Research Policy, Vol. 3, Issue 3, pp.258-291.
2. For example, Morrison, P.D., Roberts, J.H., von Hippel, E. (2000) Determinants of user innovation and innovation sharing in a local market. 'Management Science'. 46, 12, pp.1513–1527; Franke, N., von Hippel E., Schreier, M. (2006) Finding Commercially Attractive User Innovations: A Test of Lead-User Theory, 'Journal of Product Innovation Management'. (23), pp.301–315.
3. For example, see Lettl, C., Herstatt, C., Gemuenden, H.G. (2006) Users' contributions to radical innovation: evidence from four cases in the field of medical equipment technology. 'R&D Management'. 36,pp.3.
4. For example, see Luthje, C., Herstatt, C., von Hippel, E. (2005) ' User-innovators and 'local' information: the case of mountain biking'. Research Policy (34)6, pp.951-965.
5. This has been widely explored in a number of publications including: von Hippel, E. (2005) 'Democratizing Innovation'. Cambridge, MA: MIT Press; Flowers, S., Grantham, A., Mateos-Garcia, J., Nightingale, P., Sapsed, J., Tang, P. and Voss, G. (2008) 'The New Inventors; how users are changing the rules on innovation'. London: NESTA; Leadbeater, C. (2006) 'The User Innovation Revolution'. London: NCC.

Part 2: User innovation: What, why, where?

2.1 A brief introduction to user innovation

This section sets out the rationale and context for this research report. It highlights a contradiction between producer models of innovation, which focus on upstream producers as the main source of innovation in the economy, and growing evidence supporting the idea that downstream users – both individual users of consumer products and firms that use process equipment in-house – play an active and significant role in processes of innovation in many sectors. This section provides an economic explanation for user innovation, and examples of user innovation activities.

For a more detailed review of research on user innovation, see Appendix 1.

What do we mean by user innovation?
User-innovators are firms or individual consumers that expect to benefit from using a novel product or a service they develop. In contrast, producer-innovators expect to benefit from selling the novel product or service they develop in the marketplace.

Individual users of consumer goods – 'consumers' – may decide to create or modify the products they use in their everyday lives in order to address needs that are not catered for by commercial products available on the market.[6] Similarly, firms use process technologies such as machinery or software to produce the goods and services which are their final outputs. These firms may create or modify process technologies in-house in order to improve their productive efficiency.

Why do users innovate?
Ever since Joseph A. Schumpeter promulgated his influential theory of economic development in 1934,[7] economists, policymakers, and business managers have assumed that innovation is dominated by producers. According to this model, specialist producers develop innovations which they then sell or license to their users, whether individual consumers or firms.

There is an economic rationale behind this assumption about the division of labour in innovation. While producers can profit from selling their innovations to large user markets, individual users depend on the benefits from their own in-house deployment of an innovation to recoup the investment on developing it. Other things being equal, a producer serving many customers should be able to invest more in developing an innovation than any single user. This means that producer-developed innovations could be expected to dominate user-developed innovations in most parts of the economy.

The traditional assumption that producers are the dominant developers of innovations has informed public policies to support innovation, with a strong focus on the incentives of producers. Producers, it is argued, innovate in order to generate profits from the sale or licensing of their innovations. If they are unable to capture the full benefits from their innovations – either because these are copied by others, or because there are information spillovers – they will invest less on innovation than would be socially desirable. This justifies government support in the form of, for example, R&D tax credits, and intellectual property frameworks that give producers a temporary monopoly over their innovations.

6. The breadth of user innovation is explored in depth in von Hippel, E. (2005) 'Democratizing Innovation'. Cambridge, MA: MIT Press.
7. Schumpeter, J.A. (1934) 'The Theory of Economic Development'. New York: Oxford University

Box 1: Industrial User Innovation

As Keith Pavitt, a scholar of innovation, showed in his study of sectoral patterns of technological change, the locus of innovation varies between sectors depending on key factors such as their industrial structure, dominant sources of knowledge, degree of knowledge appropriability and user requirements (Pavitt, 1986).[8] Pavitt found that in what he defined as 'production intensive' sectors, firms invest significant resources on the development of innovations for in-house use – in some of them, for example the automobile industry, the ability to improve the effectiveness of manufacturing processes is a key driver of competitiveness.

Machine tools and scientific instruments are other areas where high levels of user innovation have been identified (von Hippel, 1986),[9] going back to the invention of the telescope by Galileo Galilei.[10] The users of these technologies face, on a day-to-day basis, unusual problems that require an immediate solution. It is often more convenient for them to develop their own innovative solutions for these problems than waiting for specialist suppliers to produce them (Lee, 1996).[11] Some of these firms adopt an entrepreneurial approach to the exploitation of their user innovations. In his study of the Warton Division of British Aerospace, Gordon Foxall found that this company licensed many of the innovations it developed for in-house use – for example, robot tools – whenever it could find a market for them (Foxall, 1985).[12]

8. Pavitt, K. (1984) 'Sectoral patterns of technical change: Towards a taxonomy and a theory'. Research Policy 13(6), pp.343-373.
9. Von Hippel, E. (1976) 'The dominant role of users in the scientific instrument innovation process'. Research Policy, 5, pp.212-239.
10. Feyerabend, P. (2008) 'Against Method'. London: Verso.
11. Lee, K.R. (1996) 'The role of user firms in the innovation of machine tools: The Japanese case'. Research Policy 25(4), pp.491-507.
12. Foxall, G. (1985) 'Customer-developed innovation'. Conceptual extension and empirical research. Cranfield School of Marketing,Occasional Papers.
13. Baldwin, C.Y. and von Hippel, E. (2009) 'Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation'. MIT Sloan School of Management Working Paper, No. 4764-09. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1502864
14. Flowers, S. (2008) 'Harnessing the hackers: the emergence and exploitation of Outlaw Innovation'. Research Policy. Vol. 37, pp.177-193; Jeppesen, L. B. and Molin M.J. (2003) Consumers as co-developers: learning and innovation outside the firm.'Technology Analysis & Strategic Management'. 15(3), pp.363-383.
15. Baldwin, C. Y. and von Hippel, E. (2009) 'Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation'. MIT Sloan School of Management Working Paper, No. 4764-09. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1502864
16. Harhoff, D., Henkel, J., von Hippel, E. (2003) Profiting from voluntary information spillovers: How users benefit by freely revealing their innovations. 'Research Policy'. 32, pp.1753–1769.
17. Chesbrough, H. (2003) 'Open Innovation: The New Imperative for Creating and Profiting from Technology'. Cambridge, MA: Harvard University Press.

But a growing body of research has shown that the producer-centred model of innovation only tells part of the story. Some users have highly specific needs that cannot be addressed effectively with the standardised 'mass' technologies and solutions available in the market. In addition, 'lead' users in fast-moving sectors might not find any producers able to provide them with the technologies that they require: their needs are so new, and the eventual market size still so unclear, that no supplier has emerged to address them yet. In all these cases, there is a clear economic rationale for user innovation to occur.

User innovation is becoming more important

This trend is a consequence of two related technological processes:

- The steadily improving *design capabilities of users*, made possible by increasingly sophisticated and affordable computer hardware and software – the widespread availability of these tools is lowering the costs and barriers for innovation by users;[13]
- The steadily improving ability of individual users to *combine and coordinate* their innovation-related efforts, particularly via the Internet – user-innovators often join or start online communities where they discuss their activities, and share tools and information. Many of these communities of enthusiasts are non-commercial in nature – firms are increasingly attempting to collaborate with them in order to harness their valuable ideas.[14]

The success of the open source software paradigm (see Box 2) shows that user innovation can be, in some circumstances, as effective or more effective than innovation by producers.[15]

The wider benefits of user innovation

User innovation can produce benefits beyond the firm or individual consumer undertaking it.[16] For example, it has been observed that innovations initially developed by users are often taken up by producers who incorporate them into the next model of a technology, and commercialise it. The operational efficiency of all the firms that acquire this new technology is thus improved.

Users can also license the innovations they have developed in-house in order to generate revenues.[17] However, and more frequently than one might expect, user-innovators freely reveal their innovations for use and commercialisation by others. Although this might seem surprising – these users have after all invested valuable time and resources in the development of

Box 2: Open-source software

Open-source software is developed by communities of volunteers who coordinate their activities through the Internet.[19] Differently from the proprietary software sold by commercial vendors such as for example Microsoft, open-source software is made available for free, along with its source code. This makes it possible for anyone to modify, extend and solve any defects that they find in its code. Open-source software is released under 'copyleft' licences such as the General Public License (GPL), which stipulate that users must share improvements and modifications with the broader community. It has been claimed that by harnessing large numbers of users as testers and problem solvers, this innovation model produces more reliable software.[20]

Open-source software has become increasingly popular in recent years, not only because it is cheaper than the proprietary alternatives, but also because the firms that adopt it can readily modify it in order to address their particular organisational or hardware needs.[21] GNU/Linux, an open-source software operating system, has for example been fitted into a wide range of platforms including tablet PCs, mobile phones and video games consoles.

Many firms are developing innovative business models that harness open-source software to generate substantial revenues – large corporations including IBM and Oracle release software they develop under open-source licenses in order to increase the attractiveness of their hardware and services. Other companies such as Red Hat test and integrate open-source applications into easy-to-use packages, and provide support to business users.

18. Harhoff, D., Henkel, J., von Hippel, E. (2003) Profiting from voluntary information spillover show users benefit by freely revealing their innovations. 'Research Policy'. 32, pp.1753–1769.
19. Weber, S. (2004) 'The Success of Open Source'. Cambridge, MA: Harvard University Press.
20. Raymond, E. (2001) 'The Cathedral and the Bazaar'. Sebastopol, CA: O'Reilly Media.
21. 'The Economist' (2009) Born Free. May 28th 2009.
22. NESTA (2007) 'Hidden Innovation: How innovation happens in six 'low innovation' sectors'. London: NESTA; von Hippel, E. (2007) Horizontal innovation networks – by and for users. 'Industrial and Corporate Change'. 16(2), pp.293-315.
23. NESTA (2006) 'The Innovation Gap: Why Policy needs to reflect the reality of innovation in the UK'. London: NESTA; (2007) 'Hidden Innovation: How innovation happens in six 'low innovation' sectors'. London: NESTA.

those innovations – it is often the case that sharing them is easier and more beneficial than hiding or protecting them.[18] Open sharing can benefit user-innovators by contributing to their reputation, eliciting reciprocity from other users, or increasing demand for complementary goods or services (Box 2).

2.2 Uncovering user innovation

The user innovation paradox

There is evidence showing that user innovation by firms and individual consumers plays an important role in many sectors: examples of the impact of these innovations have been collected over the years, and for many countries (see Appendix 1 for a review of these studies). However, and in spite of being an important feature of industrial and commercial life, user innovation has remained largely 'hidden' from policymakers, partly because, as it was noted earlier, it does not fit with dominant, 'producer-centred' understandings of the innovation process. As a consequence, almost no attempts have been made to measure and incorporate it into official statistics.[22]

A wider definition of innovation is gaining traction, and it has user innovation at its core

Today there is a widespread recognition that the producer model of innovation fails to capture the complexities of modern innovation processes. It is also becoming increasingly clear that established metrics of innovation, such as R&D expenditure, patent and publications data, capture only a small subset of innovative activities.

Internationally, the Organisation for Economic Co-operation and Development (OECD) is developing an innovation strategy to provide policymakers with tools to improve their own innovation strategies in a global market. The strategy, based on the broader definition of innovation presented in the third edition of the *Oslo Manual* (OECD/Eurostat 2005), is expected to incorporate a discussion of user innovation. When it is delivered this year, this new strategy is likely to lead to a major shift in the international standards that govern the measurement and management of innovation at the country level.

NESTA has participated in this debate through the publication of several studies[23] highlighting the limitations of traditional innovation

Box 3: Firm-level user innovation survey in Canada

Canada's national statistics agency, Statistics Canada, was one of the first bodies to systematically examine aspects of user innovation using large-scale surveys of industrial and consumer activity. The first large-scale survey providing evidence of firm-level user innovation was the 1998 Statistics Canada survey of Advanced Manufacturing Technologies. Designed to investigate the extent to which Canadian manufacturing firms use advanced technologies in their processes at the unit or 'plant' level, the survey was based on a sample of 4,200 firms with more than ten employees. The study revealed that although the preferred method of acquisition of advanced manufacturing technology was by simply purchasing off-the-shelf equipment (84 per cent)[24] an important fraction (26 per cent) of the firms had created their technologies by either customising or significantly modifying an existing technology. Further, a large proportion (28 per cent) had developed new technologies in-house[25] This finding indicated that an important proportion of Canadian manufacturing firms were user innovators and that process technology modification and creation – key aspects of firm-level user innovation – were widespread.

Additional aspects of process innovation by Canadian manufacturing firms were explored in the 2007 survey of Advanced Manufacturing Technology. This utilized separate follow-up surveys for firms that modify existing technologies and firms that develop brand new technologies. The follow-up surveys were designed to examine a range of issues including the way in which technologies were created or modified, how the innovations were diffused, and firm expenditures. The two surveys[26] indicated that 35 per cent of modifying firms and 50 per cent of firms that develop brand-new technologies were engaging in user innovation on an ongoing basis. The surveys also found that although almost all firms (98 per cent) funded these innovation activities from their own resources, the mechanisms differed and formal R&D budgets were often not the main source of funds. The most important source of funds for firms that modify technologies was the maintenance budget (52 per cent), whilst for firms that develop new technologies the most important source was the R&D budget (54 per cent).

24. Sabourin, D. and Beckstead, D. (1999) 'Technology adoption in Canadian Manufacturing. Survey of advanced technology in Canadian manufacturing'. Ottawa: Statistics Canada.
25. Arundel, A. and Sonntag, V. (1998) 'Patterns of Advanced Manufacturing Technology (AMT) Use in Canadian Manufacturing: 1998 AMT Survey Results'. Research Paper 88F0017MIE (Ext. r. no.). Ottawa: Statistics Canada.
26. Gault, F. and von Hippel, E. (2009) 'The prevalence of user innovation and free innovation transfers: implications for statistical indicators and innovation policy'. MIT Sloan School of Management, Working Paper No.4722-09. Cambridge, MA: MIT Press.
27. NESTA (2009) 'The Wider Conditions for Innovation in the UK: How the UK compares to leading innovation nations'. London: NESTA.

indicators, and exploring types of innovation that, not being captured in official statistics, remain 'hidden' from policymakers. The *Innovation Nation* White Paper published in 2008 acknowledged the importance of 'hidden innovation' to the UK's economy and society, and identified users as a significant source of innovation.

Governments overseas have already started to quantify user innovation

Statistics Canada, the Canadian statistical service, has collected data on user innovation in the advanced manufacturing sector, while the Netherlands research organization EIM is exploring user innovation as part of its SMEs and Entrepreneurship Programme, funded by the Dutch Ministry of Economic Affairs (see Boxes 3 and 4).

User innovation as part of the Innovation Index

NESTA's Innovation Index has identified the important role that demand has on shaping successful innovations.[27] Much of the evidence to support this stems from the producer-consumer model. This study, however, highlights the dynamic nature of the consumer role in shaping and creating new products. To date the evidence to support this has focussed on the user innovation role of firms.

The analysis in the following sections sets out to develop a new generation of indicators that capture innovative activities which have until now remained hidden from policymakers. A robust set of indicators, quantifying more widely defined sources of innovation, will help to formulate policies better able to support innovation, wherever it occurs. These new indicators will offer an original perspective on the dynamic role of consumers demand.

Box 4: Firm-level user innovation survey in the Netherlands

Recent work in the Netherlands[28] has examined user innovation in SMEs. This survey, organised by EIM Business and Policy Research and financed by the Ministry of Economic Affairs, was based on 2,416 responses from firms with between 1-100 employees. The survey focused on user creation of and user modification of *'… techniques, equipment or software …'* excluding product modifications on behalf of customers. This survey also collected data on diffusion and expenditure. The survey also examined firm-level process innovations in order to explore its similarities with process innovation.

The survey revealed that around 22 per cent of Dutch SMEs were user-innovators. Of these, 18 per cent were Modifiers, and 4 per cent New Technology Developers. On a sector level it was found that manufacturing firms had the highest proportion of user innovators (Modifiers: 31 per cent; New Technology Developers: 11 per cent), followed by Business Services (Modifiers: 21 per cent; New Technology Developers: 6 per cent), and Farming (Modifiers: 20 per cent; New Technology Developers: 4 per cent). The lowest reported level of user innovation was by the Lodging and Meals sector (Modifiers: 10 per cent; New Technology Developers: 1 per cent).

A survey of high-technology SMEs in 2007 undertaken by EIM Business and Policy Research also explored the incidence and nature of user innovation. This survey included responses from 498 high-technology SMEs drawn from a panel sample composed of firms with between one and 100 employees operating in knowledge-intensive activities.

In terms of the diffusion of the innovations created by these user firms, it was found that 25 per cent of all user innovations had been transferred to firms higher up the supply chain for commercialisation and general diffusion to others via the marketplace. Very importantly, it was the more generally useful of the user-developed innovations that had been transferred to producers for general sale.

Of those innovations that were transferred to producers, nearly half (48 per cent) were given away at no cost, with the bulk of the remainder (39 per cent) being transferred on the basis of some form of informal payment. Just 13 per cent of the user innovations were transferred subject to formal royalty agreements, and only 13 per cent of the firms had protected their innovations via some form of intellectual property rights.

28. de Jong, J.P.J. and von Hippel, E. (2009) Transfers of user process innovations to process equipment producers: A study of Dutch high-tech firms. 'Research Policy'. (September) Vol. 38, No. 7, pp.1181-1191.

Part 3: Survey of user innovators at the consumer level

3.1 The measurement of user innovation by individual consumers breaks new ground

User innovation by consumers has been widely documented in the academic literature for sectors as diverse as extreme sports, computer games, software, music and music software tools, clothing, automobiles or bicycles. (See Appendix 1 for details). However, until the present study there have been no attempts to explore the frequency of this phenomenon within a general consumer population.

Methodology and data for the consumer-level survey

A two-stage approach featuring two separate consumer surveys has been adopted in order to establish the importance of user innovation within the UK consumer population.

First, a closed questionnaire survey explored the incidence of user innovation within a representative population of UK consumers. This survey targeted a weighted, representative sample of 2,019 respondents older than 15 years of age. It examined several activities typically associated with user innovation, such as the creation and modification of physical products used by consumers – for example, bicycles or kitchen equipment – and the creation and modification of software.

The results of this survey helped to identify segments of the UK consumer population that are particularly active in developing or modifying products they use as consumers. Three-hundred respondents within these more active segments were then targeted with a more detailed survey instrument. A primary goal of this second survey was to validate instances of reported user innovation according to strict criteria in order to establish the reliability of the findings of the previous closed-questionnaire survey.

Written descriptions of the reported user 'innovations' were examined. All cases of innovations that respondents had developed as part of their jobs were excluded, as were all instances where the innovations had been developed for commercial – rather than user – purposes. Reported 'innovations' that were simply homemade replicas of products already available on the marketplace were also excluded. Since the sample should include only truly novel innovations, modifications and improvements that manufacturers had anticipated users would undertake and had made provisions for – such as software upgrades – were also excluded.

Applying these strict criteria led to the exclusion of a large number of the innovations reported, and to the computation of correction factors which were applied to the results of the original omnibus survey in order to produce the findings on user innovation by consumers that are presented in Section 3.2 of this report.

Appendix 2 presents the data collection process for the consumer level survey in further detail.

3.2 The consumer level findings

Substantial numbers of UK consumers create or modify consumer products

The conservatively adjusted results of the omnibus survey show that 8 per cent of all respondents engage in user innovation by creating or modifying products or software they use in their daily lives with the goal of

Box 5: User innovations amongst UK consumers

As might be expected, user innovation amongst consumers tends to involve everyday household items, although there are also some notable examples of software-related innovations.

There are several examples of individual consumers modifying their cars in order to make them faster or to customize them in other ways by, for example, adding self-designed suspensions for racing or other specialised uses. There were also a number of instances of consumers innovating in sport-related products by, for example, modifying their golf clubs or fishing rods, or redesigning the rigging of their sailing boat.

Consumers also modify and create tools such as screwdrivers and spanners regularly. They create devices to hold work and guide tools, and even develop new tools from scratch – for example one consumer developed a right-angle screwdriver. Innovative activity around gardening equipment was also present. Modifications to lawnmowers, garden trimmers, pressure washers and tree loppers were mentioned by respondents.

Some specific instances of innovation by consumers that have been identified in the detailed survey include an automobile with a modified electrical system enabling the connection of video games consoles in the back seats, or an MP3 player customised so it can be controlled with a specialised programming language. Another respondent had developed a software program enabling him to catalogue his CD collection in far more detail than commercially-available systems would allow. Individuals also built complex items, such as computers, bicycles, toys and go-karts from scratch. One consumer built an automatic feeder for their dog, whose diabetes meant that it required regular and precise feeding during the day. Another interviewee reported creating their own lightweight gas camping cooker.

29. Consumer omnibus survey (n=2109), weighted results.

better addressing their own personal needs. If the results of this representative survey were extrapolated to the UK population above 15 years old, this would mean that potentially over three million people in the UK are engaged in user innovation activities linked to the creation or modification of consumer products and software. This number does of course exclude the innovation activities of people under the age of 15 – it would be even higher if they were included.

As Table 1 shows, consumers are more likely to innovate by modifying existing products than by creating new ones from scratch: 5.2 per cent of respondents modify the software or physical products they use, and 4.4 per cent create them from scratch.[29]

The survey shows that consumers innovate more frequently on the physical products they use than they do on software. This might be because users lack the technical skills to modify or write software, or find it less necessary to do so in comparison to physical products.

Consumer innovations are often diffused to peers and producers

The omnibus survey included two key questions to explore the extent to which consumers develop innovations which are useful to others. First, respondents were asked if they believed that they had been the first to

Table 1: Overall levels of user innovation by consumers (percentage of respondents to the omnibus survey)

	User innovation (overall)	Modification	Creation
Overall	8%	5.2%	4.4%

Table 2: Novelty and diffusion of user innovations by UK consumers

	UK consumers aged 15+ with a user innovation in the past three years		
	User innovation (overall)	Modification	Creation
Total (n=2,109)	8.0%	5.9%	4.4%
Of which:			
Consumer perceives self to be first to develop the innovation (n=2,109)	3.4%	1.9%	1.7%
Consumer knows others that have adopted the innovation (n=2,109)	2.0%	1.8%	0.5%

produce the reported innovations. Second, they were asked if they were aware of any other parties (including consumers and/or firms) that had adopted their innovations.

As can be seen in Table 2, 3.4 per cent of all respondents to the omnibus survey report that they have produced a novel innovation that was not available in the market and that was not a copy of something that other users had developed earlier. Some 2 per cent report that their user innovations have been adopted by others – peer users and/or producers. In other words, nearly half of all user innovations developed by consumers incorporate functionalities which, to the best of their knowledge, did not exist previously. Furthermore, a quarter of the innovations developed by consumers were taken up by others.

Characteristics of consumer-innovators in the UK population

Male consumers engage in user innovating about twice as often as women.[30] People over 65 years of age tend to innovate less frequently than other age groups. People with the highest level of formal education tend to innovate about twice as often as those with the least formal education.

30. It has been suggested that this gender gap may be due at least in part to a lower likelihood of women reporting their innovations to interviewers. Further research is needed to clarify this.

Table 3: Incidence of user innovation by gender (share of user innovators in each category)

	User innovation (overall)	Modification	Creation
Men (n=944)	11.3%	8.5%	6.2%
Women (n=1,165)	5.0%	3.4%	2.6%
Total (n=2,109)	8.0%	5.9%	4.4%

Table 4: Incidence of user innovation by age (share of user innovators in each age interval)

	User innovation (overall)	Modification	Creation
15-24 years (n=251)	10.3%	8.1%	5.3%
25-34 years (n=327)	9.6%	7.1%	5.5%
35-44 years (n=381)	8.8%	6.6%	4.1%
45-54 years (n=360)	8.3%	5.7%	4.8%
55-64 years (n=300)	8.0%	5.6%	5.1%
65+ years (n=490)	4.1%	2.8%	2.0%
Total (n=2,109)	8.0%	5.9%	4.4%

Table 5: Incidence of user innovation by highest educational attainment (share of each category)

	UK consumers aged 15+ with a user innovation in the past three years		
	User innovation (overall)	Modification	Creation
Below secondary education (n=383)	4.9%	3.5%	1.9%
Secondary education (n=642)	6.4%	4.6%	3.4%
High School education (n=274)	9.5%	7.1%	5.3%
Further qualifications (n=379)	8.7%	6.2%	4.9%
Degree/post graduate/professional (n=427)	11.8%	8.8%	7.0%
Total (n=2,109)	8.0%	5.9%	4.4%

Part 4: Survey of user innovators at the firm level

4.1 The firm-level user innovation survey builds on similar studies in other countries

The survey of user innovation by firms presented in this report builds on and extends similar studies carried out in Canada and the Netherlands, as discussed previously in Part 2. The survey adapts the methodology and survey instrument used in the Netherlands to the UK context, and applies it to firms from a broader sample of industrial sectors.

Methodology and data for the firm-level survey

The survey of user innovation at the firm level includes 1,004 responses from firms drawn from a structured sample that is representative of the UK economy. Firms were contacted by telephone, and responded to a detailed questionnaire designed to explore their user innovation activities. User innovation was disaggregated into two kinds of activities: 'modification of externally acquired technologies'; and 'creation of new technologies from scratch'.

The survey collected data on the amounts of labour invested in user innovation projects; types of collaborators in user innovation activities; efforts to protect or share user innovations; and whether any user innovations developed had been adopted by others, and if so, under what terms. Firm responses were recorded using a computer assisted telephone interviewing system and the data was checked independently by two researchers in order to ensure that reported examples of user innovation were valid. This screening enabled the identification and exclusion of 'false positives', that is, reported instances of user innovation which did not meet the criteria for user innovation established by the researchers (which were analogous to those indicated for the consumer level survey).

In order to avoid a sampling bias, the same number of firms were surveyed in each sector, and the results of the survey were then weighted to reflect the importance of the sector in the economy as a whole. It is these weighted results that are presented below.

4.2 The firm-level findings

There are significant levels of user innovation amongst respondents to the survey

Over 15 per cent of respondents to the firm-level survey report that they have engaged in some form of user innovation over the last three years. Within this overall level of user innovation, most firms – 10.3 per cent of the total – have engaged in the modification of

Table 6: User innovation activities for all firms (share of all respondents)

User innovation (overall)	Modification	Creation
15.3%	10.3%	8.6%

Box 6: User innovation amongst UK firms

User firms often create equipment and machinery to use in their own production processes. Examples from the survey include a firm that created its own equipment to produce contact lenses, as well as another that developed a novel machine to mark stainless steel parts of their products.

Firms frequently modify process equipment to adjust their production systems to their specific needs. For example, a firm reported having modified the laser-guided vehicles it uses to pick up paint and automatically deliver it across its factory. A farm modified cabbage peeling and washing machines to better suit its production needs.

User innovator firms also develop software systems from scratch. One firm reports the creation of a software system to streamline business operations. The system, which is compatible with Microsoft Word and Excel, includes a client database, the linking of suppliers with other users and credit control for client accounts. Another firm created stock monitoring and goods location systems.

Software modification by user firms can help to address in-house needs more effectively. For example, a hotel firm modified software for all its services such as reservation systems, and systems related to food and beverage ordering. User firms also modify software in order to streamline administration systems. A firm reported having adapted its HR software package to make it easier to store company data, and to store other materials in the same programmes. An agricultural firm modified its customer relations system and the system to monitor the collection of the statutory potato levy.

process technologies acquired from other sources. An important minority of firms – 8.6 per cent – have created their own process technologies from scratch.[31]

Table 6 shows a substantial share of user innovators among a broad sample of firms that basically represents all commercial businesses in the UK with 10-250 employees. Previous surveys of this type identified even higher levels of user innovation – in a sample of Canadian manufacturers with more than 20 employees the share of user innovators was 40 per cent; and among Dutch high-tech small and medium sized enterprises, it was 54 per cent.

Some of these differences might be a consequence of the focus that these studies placed on larger firms, as well as those in high-technology sectors, who could be expected to engage more actively in user innovation activities.

Types of innovations user firms develop

Users report innovating on their process software about twice as often as they report developing or modifying process equipment (Table 7).

Not all software can be freely modified or extended by its user firms. These activities are often much more difficult in the case of proprietary software, which is not distributed with its source code. However, open-source software, which can be freely downloaded and modified by anyone, is becoming more widely adopted by businesses.

31. The overall level of user innovation shown in Table 6 is smaller than the sum of 'modification' and 'creation' activities because some firms engage in both kinds of activities.

Table 7: User innovation activities by type of technology (share of total respondents)

	Overall level of user innovation	Modification	Creation
Process Software	11.3%	7.7%	5.9%
Process Equipment	5.5%	3.5%	2.9%

Firm-level user innovation varies widely across sectors

The survey shows strong variation in the levels of user innovation across different industrial sectors. As can be seen in Table 8, software and IT services have the highest frequency of user innovation. Hotels and restaurants, transport and communication, and construction report the lowest levels.

Modification of externally acquired technologies is more frequent than new technology creation in most sectors. This probably reflects the additional challenges and costs of innovating 'from scratch'. The exception to this finding is Aerospace and Automotive, where user innovators create new technologies as often as they modify externally acquired ones.

Larger firms are more active user innovators

User innovation is more frequent amongst large firms (Table 9). This disparity is present for both types of user innovation activities. Larger firms report levels of user innovation through modification at well over twice the level of smaller firms. This result might reflect the higher levels of capability and resources that such firms can deploy in the development of technologies to tackle the challenges they face internally. It is also likely to reflect the higher returns from process innovations accruing to firms that produce in higher volumes.[32]

32. Klepper, S. (1996) Entry, Exit, Growth, and Innovation over the Product Life Cycle. 'American Economic Review.' 86 (3), pp.562-83.

Table 8: User innovation activities by sector (user innovation activities as a share of total number of respondents in each sector).

	Total user innovators	User modifiers	User creators
Software and IT services	50%	40.6%	21.9%
Mining and quarrying	33.3%	33.3%	0%
Other Creative Activities	24.7%	15.1%	12.2%
Other manufacturing	23.2%	15.4%	14.9%
Aerospace and automotive	20%	16.7%	16.7%
Financial services	18.5%	14.8%	11.1%
Other business services	17%	12.3%	8.6%
Wholesale trade	16.7%	10.4%	9.1%
Legal, consultancy and accounting services	15.4%	7.8%	9.8%
Agriculture and fishing	14.3%	7.7%	7.7%
Retail trade and personal services	8.30%	3.3%	5%
Transport and communication	7.4%	4.9%	4.9%
Hotels and restaurants	6.3%	4%	4%
Construction	5.8%	5.8%	1%
Energy production	0%	0%	0%

Total user innovators is less than the sum of user modifiers and user creators because some firms both modify and create.

Table 9: User innovation activities by firm size (share of all respondents in each size interval)

	User innovation (overall)	Modification	Creation
1-49 employees	12.6%	7.9%	7.3%
50-250 employees	27.4%	19.9%	13.5%

User firm expenditures on developing and modifying process equipment and software they use

The average expenditure on equipment and materials for process equipment and software innovation during the past three years was £44,553 per firm. There was a wide range of reported expenditure, with some firms spending little or nothing, and one user firm reporting that it invested £2 million in user innovation during the last three years.

Data were also collected on the time and personnel devoted to user innovation activities (Table 10). Once again, the range of reported values varies greatly, with project durations ranging between one day and 1,575 days, and project teams ranging in size between two and 28 staff. The median user innovation project involves five members of staff, and lasts 40 days. More time is invested on modification than creation activities, and there is little variation between the time and staff that firms of different sizes commit to user innovation.

A significant finding is that small and medium user innovator firms (with between ten and 49 employees) commit a median of five people to user innovation projects, a substantial share of their staff.

Some user innovations are shared freely with other users, as well as suppliers

Overall, 10.9 per cent of user innovating firms report that they have shared their innovations with their suppliers. Some 5.7 per cent of these have shared without any charge, while 3.5 per cent have received either a fee or royalty payment. The survey also revealed that 59 per cent of user innovators have not attempted to protect their user innovations via any form of intellectual property rights.

Table 10: Investments on user innovation by activity and size (averages and medians for all user innovators inside each category)

	Number of contributors (mean)	Number of contributors (median)	Time investment (mean days)	Time investment (median days)
Total	8.9 (n=177)	6 (n=177)	107 (n=103)	40 (n=103)
Type				
User modification	9.1 (n=103)	6 (n=103)	126 (n=66)	40 (n=66)
User creation	7.5 (n=86)	5 (n=86)	64 (n=58)	23 (n=58)
User innovation	8.6 (n=154)	6 (n=154)	107 (n=103)	40 (n=103)
Size				
10-49	8.25 (n=119)	5 (n=119)	108 (n=70)	40 (n=70)
50-249	10.1 (n=58)	7 (n=58)	103 (n=33)	40 (n=33)

Part 5: Conclusions

5.1 Implications of the UK consumer survey

The survey of consumer innovation in the UK has documented the widespread design and development of consumer products by consumers themselves – independent of producer involvement. The innovation activities by users documented in the survey is not the same as 'co-creation' processes where consumers and producers work together to develop a product. It also is different from what are often called 'user-driven' innovation methodologies where the responsibility for new product development stays with producers, but incorporating user feedback from very early in the design process, often using ethnographical approaches. By contrast, what has been documented in this survey is innovation by users of consumer products without producer involvement.

It has not been possible to produce reliable data on the time and expenses incurred by individual consumers during their user innovation activities as part of the first, representative survey. Nevertheless, given the scale of the phenomenon, it could be expected that even small individual expenditures in time and money will add up to significant amounts, possibly higher than investments on product development by UK consumer goods firms. For example, if each of the potential population of over three million user-innovators in the UK spent only £30 every year on their individual innovation activities – a small amount for a consumer hobby – this would mean an overall investment of over £90 million on user innovation by consumers.

The results of the survey show that innovations developed by individual consumers tend not to be protected using intellectual property rights, and are in some cases taken up by producers who commercialise them. In this sense, the innovative activities of individual consumers are a source of potentially valuable 'spillovers' of innovation-related information into the wider economy.

Taken together, these two findings have important implications for policymaking and corporate practices

With respect to policymaking, the innovative activities of individual consumers are a potential source of spillovers contributing to social welfare, and might deserve further encouragement. Policymakers should also take into account the innovative activities of individual consumers when considering policies that might reduce their freedom to tinker with and modify the products they buy.

Regarding corporate practices, firms should start considering the benefits of user innovation, as well as its costs. Producers often attempt to prevent users from modifying their products.[33] But when users have the chance to modify commercial products, they often develop and field-test prototype designs that might be very valuable for producers, for instance as a source of ideas for new and improved product lines.

For example, the entire application of using inkjet printers to print fine photographs was developed by photographer-users – not by printer manufacturers. These highly-motivated users emptied out the ink cartridges sold with their printers and refilled them with inks more suitable to the novel application – inks which are now sold by printer producers. This user-developed application has become a major source of profits for printer suppliers who

33. Varian, H.R. (2002) New Chips Can Keep a Tight Rein on Consumers. 'New York Times'. July 4.

initially tried to discourage users from tinkering with their products.

5.2 Implications of the firm-level findings

New knowledge is a non-rival, partially excludable good – someone's use of a design does not inherently preclude its use by others.[34] With rare exceptions, for example the case of dangerous goods, society benefits if designs are freely available for anyone to use or improve upon.[35]

Historically, dynamic considerations have justified the enforcement of intellectual property rights that create temporary monopolies over valuable knowledge (such as that embodied in innovations): it is generally assumed that in the absence of such monopolies, producers would lack any incentives to innovate.

However, and as the firm-level survey presented in this report has shown, it is not only profit-motivated producers who develop valuable innovations. User firms often create innovative process technologies that improve their efficiency and competitiveness – these businesses are motivated by the benefits of using these technologies, not their sale. The firm-level survey has also shown that most of these innovations are not protected through intellectual property rights. Furthermore, they are often transferred to process equipment and software producers at no charge. This free transfer of innovation-related knowledge can enhance social welfare in comparison to monopolistic control over such knowledge

A traditional lack of awareness of user innovation, and the extent of 'free revealing' taking place in the economy has meant that most policies to encourage innovation have favoured widening in the scope of protection, as this is perceived to increase incentives for innovation by producers who are able to reap the benefits of exclusivity. But the results of the firm-level survey highlight the need to balance this approach with other measures that encourage the free revealing of innovations by users. Otherwise, there is the risk that innovations developed by users that could have been beneficial to others, end up not being shared, and that valuable innovation resources are inefficiently allocated to 're-inventing the wheel', that is, producing solutions to problems that have already been successfully addressed elsewhere.

These measures include:

- Augmenting intellectual property rights frameworks to support 'open' licenses such as Creative Commons in the case of content or the General Public License for software.[36] The remit of existing intellectual property offices could be extended to maintain a register of the innovations and content released under these licenses. It is also important to ensure that user-innovators not seeking formal IP protection cannot be opportunistically excluded from using their own inventions by others.[37]

- Laying down a low-cost, high-bandwidth broadband infrastructure that supports the adoption of distributed models for collaborative innovation, where the private returns to free revealing are higher for users.[38]

- Putting in place a system analogous to R&D tax credits – providing incentives for user innovators to document and share the results of their private innovation activities. Documentation could take a form analogous to a patent disclosure, vetted for novelty by patent office examiners.

5.3 User innovation going ahead

This report suggests that we are in the midst of a major shift in the way innovation gets done in advanced market economies. As design and communication costs decline – due to rapid improvements in computer-based design tools and Internet-enabled communication channels – open collaborative innovation models, very often led by users, are becoming viable under a steadily wider range of conditions.[39] This has important implications for government innovation policies and firm innovation practices.

New indicators should be developed so that government can track innovation and its diffusion by UK consumers and user firms on a regular basis. More accurate data on the nature and extent of the phenomenon will inform the formulation of UK policies better able to support and harness this very important UK innovation resource. The evidence presented in this report is a first step in that direction.

34. Romer, P.M. (1990) Endogenous Technological Change. 'Journal of Political Economy'. 98(5), pp.S71-S102.
35. Machlup, F. and Penrose, E. (1950) The Patent Controversy in the Nineteenth Century. 'Journal of Economic History'. 10(1), pp.1-29; Nelson, R. (1959) The Simple Economics of Basic Scientific Research. 'Journal of Political Economy'. 67(3), pp.297-306; Arrow, K.J. (1962) Economics of Welfare and the Allocation of Resources for Invention. In: 'The Rate and Direction of Inventive Activity'. (R.R. Nelson ed.) Princeton, NJ: Princeton University Press, pp.609-625.
36. O'Mahony, S. (2003) 'Guarding the Commons: How Open Source Contributors Protect their Work'. Research Policy 32(7), pp.1179–1198.
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39. Baldwin, C.Y. and von Hippel, E. (2009) 'Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation.' MIT Sloan School of Management Working Paper, No. 4764-09. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1502864

Appendix 1: User innovation – state of the field

Importance of innovation by users
Users are firms or individual consumers that expect to benefit from using a product or a service. In contrast, suppliers expect to benefit from selling a product or a service. A firm or an individual can have different relationships to different products or innovations. For example, Boeing is a manufacturer of airplanes, but it is also a user of machine tools. Any innovations undertaken by Boeing to improve the metal-forming machinery it uses use to build airplanes would be categorized as user-developed innovations. In those cases, Boeing would be a user innovator.

Innovation user and innovation manufacturer are the two general 'functional' relationships between innovator and innovation. Users are unique in that they alone benefit directly from innovations. All others (here lumped under the term 'suppliers') generate most of their profits from the sale or licensing of innovative products or services to users, indirectly or directly. Similarly, suppliers of innovation-related materials or services – unless they have direct use for the innovations – must sell the materials or services in order to profit from their innovations.

This way of thinking about the relationship about an innovator and an innovation can be applied to specific functions, attributes, or features of products and services. When this is done, it may turn out that different parties relate in different ways with specific attributes of a particular product or service. For example, someone who lives in a house uses the switching attribute of a household electric light switch to turn lights on and off. However, switches also have other attributes, such as 'easy wiring' qualities, that are mostly used by the electricians who install them. Therefore, if an electrician were to develop an improvement to the installation attributes of a switch, this would be considered a user-developed innovation.

Both qualitative observations and quantitative research in a number of fields have documented the important role that users play as first developers of products and services later commercialised by manufacturing firms. Adam Smith (1776) was an early observer of the phenomenon, pointing out the importance of *"…the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many."* Smith went on to note that *"a great part of the machines made use of in those manufactures in which labour 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."*

Rosenberg (1976) explored the matter in terms of innovation by user firms rather than individual workers. He studied the history of the US machine tool industry, finding that important machine types like lathes and milling machines were initially developed and built by the user firms who first needed them. Textile manufacturing firms, gun manufacturers and sewing machine manufacturers also were important early user innovators of machine tools.

Quantitative studies of user innovation document that many of the most important and novel products and processes in a range of fields have been developed by user firms and by individual users. Thus, Enos (1962) reported that the majority of important innovations

in oil refining were developed by user firms. Freeman (1968) found that the most widely licensed chemical production processes were developed by user firms. Von Hippel (1988) found that users were the developers of about 80 per cent of the most important scientific instrument innovations, and also the developers of most of the major innovations in semiconductor processing. Pavitt (1984) found that a considerable fraction of invention by British manufacturing firms was for in-house use. Shah (2000) found that the most commercially important equipment innovations in four sporting fields had been developed by individual users.

Table A1: Studies of user innovation frequency

Innovation Area	Number and type of users sampled	Percentage of developing and building product for own use
Industrial products		
1. Printed circuit CAD software (a)	136 user firm attendees at a PC-CAD conference	24.3%
2. Pipe hanger hardware (b)	Employees in 74 pipe hanger installation firms	36%
3. Library information systems (c)	Employees in 102 Australian libraries using computerized OPAC library information systems	26%
4. Medical surgery equipment (d)	261 surgeons working in university clinics in Germany	22%
5. Apache OS server software security features (e)	131 technically sophisticated Apache users (webmasters)	19.1%
Consumer products		
6. Outdoor consumer products (f)	153 recipients of mail order catalogues for outdoor activity products for consumers	9.8%
7. 'Extreme' sporting equipment (g)	197 members of four specialised sporting clubs in four 'extreme' sports	37.8%
8. Mountain biking equipment (h)	291 mountain bikers in a geographic region known to be an 'innovation hot spot.'	19.2%
Multi-industry process innovation surveys		
9. 'Advanced manufacturing technologies' (i)	Canadian manufacturing plants in nine manufacturing sectors (less food processing) in Canada, 1998 (population estimates based upon a sample of 4,200)	28% developed 26% modified
10. 'Advanced manufacturing technologies' (j)	16,590 Canadian manufacturing establishments that met the criteria of having at least $250,000 in revenues, and at least 20 employees.	22% developed 21% modified
Any type of process innovation or process modification (k)	Representative, cross-industry sample of 498 'high tech' Netherlands' SMEs	41% developed only 34% modified only 54% developed and/or modified

Source: (a) Urban and von Hippel (1988); (b) Herstatt and von Hippel (1992); (c) Morrison *et al.* (2000); (d) Lüthje (2003); (e) Franke and von Hippel (2003); (f) Lüthje (2004); (g) Franke and Shah (2003); (h) Lüthje *et al.* (2002); (i) Arundel and Sonntag 1999; (j) Gault and von Hippel 2009; (k) de Jong and von Hippel 2009.

Empirical studies also show that a large fraction of users – from 10 per cent to nearly 40 per cent depending on the sector surveyed – develop or modify products. This has been documented for specific types of industrial products and consumer products, and in two large, multi-industry studies of process innovation in Canada and the Netherlands as well (Table A1). These findings show that users undertake high levels of product creation and modification a wide range of fields.

Studies of user innovations at both the firm and individual consumer-level show that they are likely to be 'lead users' (Urban & von Hippel 1988, Herstatt and von Hippel 1992, Olson and Bakke 2001, Lilien *et al.* 2002). This means that they are ahead of the majority of users in their market with respect to an important trend, and they stand to benefit strongly from developing a solution addressing their needs. The statistical relationship between innovation by users and lead user status have been found to be highly significant (Franke and Shah 2003, Lüthje *et al.* 2002 and Morrison *et al.* 2000).

Since lead users are at the cutting edge of the market, one would expect that many of the innovations they develop for their own use will eventually appeal to other users, and so might be eventually commercialised by specialist suppliers. The available evidence supports this hypothesis – several studies have shown that many of the innovations reported by lead users have commercial potential and/or have actually been commercialised by suppliers.

It has been established that the two defining characteristics of lead users are highly correlated with the likelihood that they will develop new or modified products (Morrison *et al.* 2004). It has also been found that the innovators displaying strong lead user characteristics tend to develop innovations which have more commercial potential (Franke and von Hippel 2003a).

Why do many users want custom products?
Sometimes users do not find the technologies that they need on the market. This is because mass producers will usually develop products that meet the needs of a large market segment, and capture significant profits. But if, as it is often the case (Franke and Reisinger 2003), user needs are highly heterogeneous, then the standardised technologies which are available in the market will leave many of them dissatisfied.

In a study of a sample of users of the security features of Apache web server software, Franke and von Hippel (2003b) found that users had very heterogeneous needs, and that many of them were willing to pay for the right technology to address them. Nineteen per cent of the users sampled innovated to tailor Apache to their needs.

Users' innovate-or-buy decisions
Even if a user cannot find in the market the technology that better suits its needs, it could still hire a specialist firm to develop it for them. One would expect these firms to be able to design and build customised products more efficiently than users could do themselves. Still, several factors can drive users to innovate rather than buy the services of a specialist supplier.

First, a user who establishes a relationship with a specialist supplier incurs agency costs. These are the costs of monitoring the activities of the supplier, as well as those that occur when the outcomes of the project do not fully address the needs of the user (Jensen and Meckling 1976). They are higher when the interests of user and supplier are not sufficiently aligned. In the specific instance of product and service development, there is a major divergence between their interests. On the one hand, the user wants to get the technology that addresses its needs best, to the extent that it can afford to do so. On the other hand, the custom producer would like to lower its development costs by incorporating into the technology components it already has, or that it expects others will want in the future – even if doing this does not meet its present client's needs as well as it could.

For example, an individual user may specify the features of a mountain-climbing boot that will precisely fit their unique climbing technique and allow them to climb more easily. Any deviations in boot design will require this climber to modify their carefully practised and deeply ingrained climbing technique. But a custom boot producer would rather make a boot that incorporates the materials and processes it has in stock and expects to use in the future, even if the results are not optimal for the present customer.

A user will thus innovate if the costs of doing so are smaller than the agency costs of contracting with a specialist supplier.

A model of the innovate-or-buy decision (von Hippel 2005) shows quantitatively that user

firms with unique needs will always be better off developing new products for themselves. It also shows that innovation by suppliers might be the best option when *n* or more user firms have the same needs. However, if the market is small or 'niche', that is, between 1 and *n*, then it might not be profitable for specialist suppliers to target it.

When this happens, some users may invest in developing a technology that addresses their needs more effectively. If too many of them 'reinvent the wheel' independently from each other, there is a waste of resources. New institutional forms, such as user innovation communities, address this problem by encouraging groups of users to share the innovations they have developed with each other.

Some individuals find innovation to be an intrinsically enjoyable activity

Some individuals prefer to innovate rather than buying an innovation from a third party because they find doing so enjoyable, or educational. Studies of open-source software communities have shown that many people who contribute to them are motivated by their passion for software development, and also because they learn from their user innovation activities (Hertel *et al.* 2003; Lakhani and Wolf 2005).

Users' low-cost innovation niches

Users and producers tend to develop different types of innovations because they tend to know different things – there are information asymmetries between them.

Developing a technology to address a need requires two types of information. They are generic solution information about how different technologies can contribute to address that need ('what technology can do') and need and context-of-use information about the specific nature of the need that has to be addressed ('what the technology should do'). These two types of information are sticky – moving them from the site where they were generated to other places is costly (von Hippel 1994).[40]

When information is sticky, innovators tend to rely largely on information they already have in stock to develop their innovations. This means that users tend to develop innovations that are functionally novel, requiring a great deal of user-need information and use-context information for their development. In contrast, producers tend to develop innovations that are improvements on well-known needs and that require a rich understanding of solution information for their development. Similarly, users tend to have better information than producers regarding ways to improve use-related activities such as maintenance: they 'learn by using' (Rosenberg 1982).

This sticky information effect is visible in quantitative studies of innovation. Riggs and von Hippel (1994) studied the types of innovations developed by users and producers of two major types of scientific instruments. They found that users are significantly more likely than producers to develop innovations that make it possible to do new things with scientific instruments. In contrast, producers tended to develop innovations that enable users to do the same things, but more conveniently or reliably (Table A2). For example, users were the first to modify instruments in order to image and analyse magnetic domains at sub-microscopic dimensions. In contrast, producers were the first to computerise instrument adjustments to improve ease of operation. The data show that sensitivity, resolution, and accuracy improvements fall somewhere in the middle. These kinds of improvements can be driven by users seeking to do new things, or by producers applying their technical expertise to improve the products along known general dimensions of merit, such as accuracy.

The existence of information stickiness implies that information on hand will also differ among individual users and producers. The information assets of a given user (or a given producer) will be closest to what is required to develop a particular innovation, and so the cost of developing that innovation will be relatively low for that user or producer. The net result is that user innovation activities will be distributed across many users according to their diverse information endowments. With respect to innovation, one user is by no means a perfect substitute for another.

Why users often freely reveal their innovations

The social efficiency of a system in which individual innovations are developed by individual users is increased if they share what they have developed with others. Producer-innovators achieve this when they sell a product or a service on the open market. But only partially – although they diffuse the product incorporating the innovation, they do so less often with all the information

40. The observation that information is often sticky contravenes a central tendency in economic theorising, where much research on the special character of markets for information and the difficulty of appropriating benefit from invention and innovation has been based on the idea that information can be transferred at very low cost. Thus, Arrow observes that "the cost of transmitting a given body of information is frequently very low. . . . In the absence of special legal protection, the owner cannot, however, simply sell information on the open market. Any one purchaser can destroy the monopoly, since he can reproduce the information at little or no cost." (1962, pp.614-15).

Table A2: Source of innovations by nature of improvement effected

Type of improvement provided by innovation	Innovation developed by:			
	% User	User	Producer	Total
(1) New functional capability	82%	14	3	17
(2) Sensitivity, resolution or accuracy improvement	48%	11	12	23
(3) Convenience or reliability improvement	13%	3	21	24
Total				**64**

Source: Riggs and von Hippel (1994).

that others would need to fully understand, replicate and adapt it.

Empirical research shows that users often do achieve widespread diffusion by 'freely revealing' the innovations they have developed. In these cases, all intellectual property rights to the information about an innovation are voluntarily given up so that all interested parties can access it – the information becomes a public good (Harhoff *et al.* 2003).

The empirical finding that users often freely reveal their innovations has been a major surprise to innovation researchers. On the face of it, if a user-innovator's costly innovations are valuable to others, one would expect the user to prevent free diffusion rather than help them to 'free ride' on it. Nonetheless, it is now very clear that individual users and user firms – and sometimes producers – often freely reveal detailed information about their innovations.

The practices of 'open-source' software developers have brought this phenomenon to general awareness. In these projects it is clear policy for project contributors to routinely and systematically freely reveal the code they have developed at private expense (Raymond 1999). However, free revealing of product innovations has a history that began long before the advent of open-source software. Allen, in his 1983 study of the 18th century iron industry, was probably the first to consider the phenomenon systematically. Later, Nuvolari (2004) discussed free revealing in the early history of mine pumping engines. Contemporary free revealing by users has been documented by von Hippel and Finkelstein (1979) for medical equipment, by Lim (2000) for semiconductor process equipment, by Morrison, Roberts, and von Hippel (2000) for library information systems, and by Franke and Shah (2003) for sporting equipment. Henkel (2003) has documented free revealing among producers in the case of embedded Linux software.

Innovators often adopt this strategy because this it is the best, or the most practical option available to them. Studies find that innovators in many fields consider that patents only have limited value (Harhoff *et al.*, 2003). For example, copyright protection and copyright licensing are applicable only to 'writings,' such as books, graphic images, and computer software.

What is more, free revealing can produce significant benefits for innovators. Users who freely reveal what they have done often find that others then improve or suggest improvements to the innovation, to mutual benefit (Raymond 1999). Freely revealing can improve a user's reputation, or produce positive network effects (i.e. when the availability of the freely revealed innovation improves the attractiveness of a complementary good that the user sells). When being the first to freely reveal a particular innovation increases these benefits, there might be a rush to do so, in the same way in which scientists strive for primacy in the publication of their discoveries.

Innovation communities

Innovation by users tends to be widely distributed rather than undertaken by a small number of very innovative users (Table A3). This means that user-innovators need to find ways to combine and leverage their efforts. They achieve this by engaging in many forms of cooperation. Direct, informal user-to-user cooperation (assisting others to innovate, answering questions etc.) is common practice.

Table A3: User innovation is widely distributed: Few users developed more than one major commercialised innovation

User samples	Number of innovations each user developed:					
	1	2	3	6	na	sample (n)
Scientific instrument users*	28	0	1	0	1	32
Scientific instrument users**	20	1	0	1	0	28
Process equipment users***	19	1	0	0	8	29
Sports equipment users****	7	0	0	0	0	7

Source: von Hippel (2005), table 7-1.

* von Hippel 1988, Appendix: GC, TEM, NMR Innovations, ** Riggs and von Hippel, Esca and AES, *** von Hippel 1988, Appendix: Semiconductor and pultrusion process equipment innovations, **** Shah 2000, Appendix A: skateboarding, snowboarding and windsurfing innovations developed by users.

Organised cooperation through communities and networks is also frequent.

The tools for coordination of innovative activities provided by these communities can increase the speed and effectiveness with which users (as well as producers) can develop, test and diffuse their innovations. They also can increase the ease with which innovators can integrate their modular innovations into larger systems – the success of open-source software communities is a demonstration of this.

The collective or community effort to provide a public good – which is what freely revealed innovations are – has traditionally been explored in the literature on 'collective action.' However, the behaviours observed in these communities depart from the conclusions of that literature in important ways. In essence, these innovation communities have more effective recruitment and reward structures than the literature would predict. A potential reason for this is that contributors in these communities obtain some private rewards that are not shared equally by 'free riders'. For example, a product that a user-innovator develops and freely reveals might be perfectly suited to that user-innovator's requirements but less so to the requirements of free riders. Innovation communities thus present a 'private-collective' model of innovation incentive (von Hippel and von Krogh 2003).

Diffusion of user-developed innovations

Innovation communities are not restricted to software and other 'information' products – they can play a major role in the development of physical ones as well. Franke and Shah (2003) have documented the important role that user innovation play in the field of sporting equipment. Nevertheless, although users can develop or modify new physical products in the first instance, the economies of scale associated with manufacturing and distributing them often makes it necessary for specialist providers to participate at some stages of the innovation process.

There are three general methods for transferring user innovations to producers for large-scale diffusion.

- **Producers can actively seek innovations developed by lead users, and subsequently turn them into commercial products:** Identifying promising innovations developed by lead users requires producers to redesign their product development processes. Currently, their market-research departments explore the needs of users in the target market and product-development groups think up suitable products to address those needs. In this type of system, the needs and prototype solutions of lead users – if encountered at all – are typically rejected as outliers of no interest. Indeed, when lead users' innovations do enter a firm's product line they typically arrive with a lag and by an unconventional route. For example, a producer may 'discover' a lead user innovation only when the innovating user firm contacts the producer with a proposal to produce its design in volume to supply its own in-house needs. Or sales or service personnel spot a promising prototype during a visit to a customer's site.

Modification of firms' innovation processes to systematically search for and further develop innovations created by lead users can provide producers with a better interface to the innovation process as it actually works, improving performance. A natural experiment conducted at 3M illustrates this possibility. Annual sales of lead user product ideas generated by the average lead user project at 3M were conservatively forecast by management to be more than eight times the sales forecast for new products developed in-house – $146 million versus $18 million per year. In addition, lead user projects were found to generate ideas resulting in new product lines, while traditional market-research methods lead to incremental improvements to existing product lines. As a consequence, 3M divisions funding lead user project ideas have experienced their highest rate of major product line generation in the past 50 years (Lilien *et al.* 2002).

- **Producers can draw user innovators into joint design interactions by providing them with 'toolkits' for user innovation:** Toolkits for user innovation involve the partitioning of product development and service development projects into subtasks, some of which require large amounts of user information. These are then assigned to users along with a kit of tools that enable them to effectively execute them. In the case of physical products, the designs that users create using a toolkit are then transferred to producers for production (von Hippel and Katz 2002).

  Toolkits make innovation cheaper for users, and increase customer value. Franke and Piller (2004) found, in a study of a consumer wrist watches, that the willingness to pay for a self-designed products was twice the willingness to pay for the best-selling commercial product of the same technical quality.

  Producers that offer toolkits to their customers increase their attractiveness as potential partners for user innovators. The custom semiconductor industry was an early adopter of toolkits. In 2003, more than $15 billion worth of semiconductors designed using this approach had been produced. (Thomke and von Hippel 2002).

- **Users can become producers, and sell their innovations commercially:** In some occasions, user innovations achieve widespread diffusion when those users become producers, for example by setting up a division to produce and commercialise their innovations. Shah (2000) showed this pattern in sporting goods fields. In the medical field, Lettl and Gemunden (2005) have shown how innovating users take on many of the entrepreneurial functions needed to commercialise the new medical products they have developed without abandoning their user roles. Recent work in this area has explored the conditions under which users will become entrepreneurs rather than transfer their innovations to established firms (Hienerth 2004, Shah and Tripsas 2004).

Adapting policy to user innovation

Determining the impact of user-innovation on social welfare will help to establish whether new policies should be put in place in order to support it. The evidence suggests that user innovation can be a source of beneficial spillovers across the economy. For example, data from both Canada and the Netherlands show that about 25 per cent of such user-developed innovations get voluntarily transferred to producers. A significant fraction – about half – are transferred both unprotected by intellectual property and without charge (Gault and von Hippel 2009, de Jong and von Hippel 2009). Henkel and von Hippel (2005) have explored the social welfare implications of user innovation, and found that social welfare is very likely to be higher in a world with user-centric innovation as compared to one where it did not exist.

Producers that base commercial products on user-developed and field tested prototypes increase their proportion of commercial successes. Freely revealed innovations by users are also likely to reduce deadweight loss caused by pricing of products above their marginal costs. When users make information about their innovations available for free, and if the marginal cost of revealing that information is zero, an imitator only has to bear the cost of adoption. This is statically efficient. The availability of free user innovations can also induce sellers of competing commercial offerings to reduce their prices, thus indirectly leading to another reduction in dead-weight loss.

This finding would imply that policymakers should support user innovation, or at least ensure that legislation and regulations do not favour producers at the expense of user-innovators in policy areas, such as intellectual property rights, where there can be conflicts.

Research undertaken in the past 30 years has convinced many academics that the current intellectual property regime is having undesirable side-effects. Intellectual property is meant to strengthen the incentives for investing on innovation. Instead, it now appears that some firms are using it in ways that are directly opposed to public welfare (Foray 2004). Major firms can create 'patent thickets' – dense networks of patent claims that give them plausible grounds for threatening to sue across a wide range of technological areas. They may do this to prevent others from introducing a superior innovation and/or to demand licences from weaker competitors (Shapiro 2001, Bessen 2003). Film, publishing and software firms can use large collections of copyrighted work for a similar purpose (Benkler 2002). The distributed nature of user innovation (where each user tends to create a relatively small amount of intellectual property) means that users are likely to be disadvantaged by such strategies. Users with small amounts of intellectual property will not be able to negotiate low-cost or cost-free cross-licensing arrangements with holders of large amounts of intellectual property – an arrangement that large holders often make with each other. As a result, these user-innovators are more likely to be blocked from opportunities to innovate.

Users (and producers) tend to build prototypes of their innovations by modifying products already available on the market to serve a new purpose. Laws such as the (U.S.) Digital Millennium Copyright Act, intended to prevent consumers from illegally copying protected works, can end up preventing users from modifying products that they purchase (Varian 2002).

It seems that, in some cases, existing intellectual property regimes favour 'information hoarding' in comparison to the 'information sharing' activities underpinning the activities of many user innovation communities. In order to address this issue, some of them have started to create 'information commons', repositories of information which is made freely available for anyone to access and modify. User-innovators can work around the strictures of intellectual property law by simply using these freely revealed substitutes (Lessig 2001). For example, in the software market, users can legally download and modify open-source software applications instead of purchasing proprietary software from commercial vendors.

Policymaking that levels the playing field between users and producers will force more rapid change onto producers but will by no means destroy them. Experience in fields where open and distributed innovation processes are far advanced show how producers can and do adapt. Some, for example, learn to supply proprietary platform products that offer user-innovators a framework upon which to develop and use their improvements (Jeppesen 2004).

Summary

Users' ability to innovate is increasing radically as a result of the steadily improving quality of computer software and hardware, and improved access to easy-to-use tools and components for innovation, and steadily richer innovation commons. Today, user firms and individual consumers have access to sophisticated programming tools for software and CAD design tools for hardware and electronics. The hardware requirements and cost of these information-based tools are decreasing. As a consequence, one would expect user innovation to continue growing even if the degree of heterogeneity in user needs, and the willingness to invest in obtaining the 'best-fit' product remain constant.

Similar innovation resources have long been available within corporations. Senior designers at firms have long been supplied with engineers and designers under their direct control, and with the resources needed to quickly construct and test prototype designs. The same is true in other fields, including automotive design and clothing design.

But as the information needed to innovate becomes widely distributed, this traditional concentration of resources for innovation on a few individuals becomes increasingly inefficient. High-cost resources for innovation support cannot be efficiently allocated to 'the right people with the right information' because it is difficult to know who they may be before they develop an innovation that turns out to have general value. When the cost of high-quality resources for design and prototyping falls, these resources can be diffused very widely, and the allocation problem diminishes in significance. The net result is a pattern in which development of product and service innovations shifts to users – something that will require producers to change their way of operating, and policymakers to revise current measures to support innovation.

Appendix 2: Methodology

The research presented in this report has three aims:

1. To develop and test indicators for user innovation by firms and individual consumers.

2. To analyse and report the levels of user innovation by users firms and consumers, and establish differences between groups of these respondents.

3. To analyse and report the extent to which user innovation reveals the presence of 'hidden innovation' not captured by traditional innovation indicators.

The data has been produced via three surveys:

- Firm survey: An in-depth survey of 1,004 UK firms with 10-250 employees.

- Initial consumer survey: A survey of 2,109 UK consumers aged 15 and over.

- Consumer follow-up survey: A more detailed survey of 344 UK consumers aged 15 and over.

This Appendix describes the data collection and sampling, respondents and indicators that were collected in each of these surveys.

Firm survey

Early studies of user innovation focused on specific products, but recently researchers have started to explore the phenomenon in broader samples of firms. These studies include the surveys by Statistics Canada and the Netherlands discussed in Section 2 (e.g., Gault and von Hippel, 2009; de Jong and von Hippel, 2008).

In these surveys, user innovation was documented for broad samples of user firms, that is, firms developing and/or modifying process equipment for their own specific purposes. The novel questions and the telephone interview techniques deployed in these surveys were refined through multiple pilot studies, and ultimately provided reliable data with a relatively low numbers of questionable cases. The research team built on these studies to design a telephone survey of 1,004 UK firms with 10-250 employees, distributed across a wide range of industries.

Sample and data collection
The research team recruited BMG Research, a market research organization located in Birmingham, UK. BMG contacted 5,678 firms drawn from the Dun & Bradstreet database, which includes all UK-based firms. As one of the aims of this research was to explore the differences between user innovation and traditional innovation indicators, micro-businesses (with less than ten employees) were excluded from the survey. This is also the case with the UK Community Innovation Survey (CIS). Firms with more than 250 employees were also excluded from the survey as there are comparatively few of them and they are relatively difficult to contact.

The data was collected between April and June 2009 using computer assisted telephone interviewing (CATI). Responses were obtained from 1,004 firms, a response rate of 17.68 per cent. All respondents were business owners or general managers.

Table A4: Distribution of respondents by industry type and size classes

Industry type	Sic codes 2003	Size class (employees)		Total
		10-49	50-249	
Mining and quarrying	10, 11, 12, 13, 14	41	26	67
Agriculture and fishing	01 to 05	41	26	67
Aerospace and automotive	34 + 35.3 + 35.41	41	26	67
Other manufacturing	15-37 (excl. 34 + 35.3 + 35.41)	41	27	68
Energy production	40 + 41	41	23	64
Construction	45	41	26	67
Wholesale trade	51	42	27	69
Retail trade and personal services	52 + 93	41	26	67
Hotels and restaurants	55	41	26	67
Transport and communicaiton	60 – 64	41	26	67
Financial services	65 – 67	42	25	67
Sofware and IT services	72	41	25	66
Legal, consultancy and accounting services	74,1	41	26	67
Other creative activities	74.2 + 74.4 + 74.81 + 92.31	41	26	67
Other business services	70 – 74 (excl. 72 + 74.1 + etc)	41	26	67
Total		**617**	**387**	**1004**

Statistical X^2-tests show that there is no evidence of selection biases in the responses for either industry type or size classes. However, the survey was disproportionally stratified and larger firms (i.e. 50-250 employees) were over-sampled at the expense of smaller ones. To obtain representative estimates for the whole population of UK firms with 10-250 employees, the data were weighted drawing on population statistics derived from the D&B database. Thus, the report only presents weighted results.

Questionnaire

The questionnaire was optimized for telephone surveying. Telephone surveys have inherently better response rates than paper or web-based interviews, and give the interviewer more opportunities to ask open-ended questions (and obtain more detailed answers). Open-ended questions were essential to document the nature of reported user innovations, and ensure the robustness of the indicators being calculated. In the earlier Dutch survey similar methods were applied. The questionnaire consisted of five sections. A summary of the topics it covered is presented in Table A5.

Section A was the key part of the questionnaire and was designed to record the incidence of user innovation in UK firms. Drawing on previous experience, four types of user innovation were distinguished. The researchers' experience in the Netherlands showed that it is not possible to document user innovation with a single indicator.

Within the survey the distinction was made between user innovation activities where existing products such as machinery or equipment are modified, and user innovation activities where new products are created from scratch. A further distinction was made between software and 'physical' products (defined as machinery, equipment and any other devices). Past experience in the Netherlands showed that respondents find it too difficult to include both forms of innovation in their answers (de Jong and von Hippel, 2008).

Respondents were asked to indicate if, in the past three years, they had undertaken any of the four types of user innovation (software modification and creation and product

Table A5: Outline of firm survey

Section	Variable	Description
A. Incidence of user innovation	a01	software modification, and nature
	a02	software creation, and nature
	a03	product modification, and nature (machinery/equipment)
	a04	product creation, and nature (machinery/equipment)
B. Networking and expenditures	b01	identification of most recent user innovation
	b02	networking: producer assistance, and motives (supplier/manufacturer)
	b03	networking: awareness of other users with similar innovations (companies/businesses/organizations)
	b04	networking: user assistance, and motives (companies/businesses/organizations)
	b05	expenditure: number of people involved
	b06	expenditure: time
	b07	expenditure: money
C. Protection and sharing	c01	protection, and nature of protection
	c02	sharing with suppliers, selectiveness, compensation and motives (producer/manufacturer)
	c03	adoption by suppliers (producer/manufacturer)
	c04	sharing with users, selectiveness, compensation and motives (user/company)
	c05	adoption by users (user/company)
D. Other	e01	business/organization size (number of employees)
	e02	industry type

modification and creation). If the answer was 'yes', they were then asked explicitly whether they had developed the innovation for their own process-related purposes. This question helped to isolate and exclude 'new product development activities' – a category that had created confusion in earlier research. Next, open-ended questions were asked to obtain a detailed description of the innovation, and to record the respondents' motives to develop it. The answers to these questions were checked afterwards to ensure that the reported examples were, indeed, user innovations.

Sections B and C were collected only if respondents reported at least one user innovation. In case of multiple reported innovations, respondents were asked to identify their most recent one. Interviewees where then asked the questions included in sections B and C in regards to this innovation. These questions addressed the involvement of other users and producers (innovation networking), expenditures in terms of time and money, the use of protection methods, and the extent to which the innovation was shared with other users.

Finally, Section D contained important background information including 'industry type' and 'firm size'.

Validation

After the survey was completed the research team checked whether the reported cases were 'true' user innovations. For this purpose, all open-ended answers were independently examined and recoded by two members of the team. Any differences were discussed and in case of any doubt, excluded from the analysis. Some examples of reported innovations, as well as the shares of false positives (i.e. reported user innovations which were not coded as

Table A6: Examples of reported innovations in firm survey

Innovation area	Coded as a user innovation	Coded as not a user innovation	False positives
Software modification	'We added an interface to the accounting system, this interface allows us to cut down on the manual input required. Once this had been developed we transferred accounts information to the subsidiary system, for easier use and less manual work. We didn't want to repetitively enter data into the system, but rather have it put in once, and allow the accounts interface to make changes with less manual work.'	'We recently modified our systems and upgraded to Microsoft Office 2007. The management of our server system was switched to a company based in Denmark. The upgrade was done on the advice of this company and because it is a better program which best suits our business needs.'	16%
Software creation	'We programmed an application to transfer manual drawings to a computerized system, to enable adjustments to be made in real time. We required a system that would be specific for in-house use as opposed to incumbent products. '	'We developed new computer games to maintain our position in the marketplace and to remain competitive. We are in the home entertainment industry. '	9%
Product modification	'The machinery that we modified was the lathe. It is the rotary turning machinery which fabricates steel components to change the shape. We added another function in order to make blocks of steel. This new function was added so that the machinery could make different things such as steel blocks that would fabricate underwater winches.'	'We upgraded to SAGE200 as we were previously on CH50. We had to do it because we modified their stock, we relocated and had to create new areas, which had to be put on the computer for sales and administrative purposes. The previous equipment was too haphazard. '	29%
Product creation	'We built small electronic modules used in the sea. There was nothing on the current market to do the job at hand and this type of equipment was specialised and tailored to suit the company's needs as and when required. '	'We developed a system to detect fingerprints for application in forensics. It was to improve our current line of products (we are a manufacturer of electronic equipment selling to police agencies). '	11%

actual user innovations during this validation) are shown in Table A6.

Although there were substantial shares of false positives, it should be noted that traditional innovation surveys suffer from similar shortcomings (Tether *et al.*, 2002; Teirlinck, 2003; Salazar and Holbrook, 2004). In the Dutch survey the 'process innovation' indicator – adapted from the one that is used in CIS surveys – gave some false positives as well, with 11 per cent of the user-reported process innovations being coded as not actual innovations by the investigators (de Jong and von Hippel, 2008).

It appears that the indicators presented in this report perform reasonably well, with 'innovations developed from scratch' being especially reliable. There is room for improvement in the case of 'innovation by modification' indicators – in their case, respondents found it difficult to distinguish between 'true' modifications and simple upgrades of modules, software or product parts.

Once the suspicious cases had been excluded, the four indicators of user innovation collected were used to build three composite indicators of user innovation. They are:

- **User modification:** including all validated user modifications of software and physical products.
- **User creation from scratch:** including all validated user creations of software and physical products.
- **User innovation:** a combination of 'user modification' and 'user creation'.

Table A7: Distribution of respondents in consumer screening survey (n=2,109)

Variable	Values and percentages
Gender	Men (45%); Women (55%)
Age class	15-24 (12%); 25-34 (16%); 35-44 (18%); 45-54 (17%); 55-64 (14%); 65+ (23%)
Social grade	AB (22%); C1 (26%); C2 (21%); D (15%); E (16%)
Standard region	London (18%); South East (23%); South West (10%); Wales (4%); East Anglia (3%); East Midlands (6%); West Midlands (6%); Yorkshire and the Humber (9%); North West (7%); North East (5%); Scotland (9%)
Employment status	Full-time (32%); Part-time (16%); Not working excluding retired (26%); Retired (26%)

Consumer survey

This research report also contains the results of a groundbreaking study of user innovation by individual consumers. Until now, studies in this area have documented the importance of user innovation focusing on specific consumer product types such as mountain bicycles. This study involves two surveys that were developed in order to explore the incidence of user innovation in a broader sample of the UK consumer population.

First, an initial survey was conducted on a representative sample of 2,109 consumers in the UK population aged 15 and over. This was a relatively short survey that was designed to chart user innovation with simple indicators. Second, an in-depth survey of 344 UK consumers who fit with the user-innovator profile identified in the initial survey was carried out. This was not a representative survey, but rather it aimed to verify the extent to which consumers report 'true' user innovations, and to collect more detailed data on specific cases.

Sample and data collection

The incidence of user innovation within a general consumer population was determined by adding a set of questions to a face-to-face omnibus survey managed by the British Market Research Bureau (BMRB), a market research organisation located in London. This omnibus survey provides a useful infrastructure for parties interested in submitting a limited number of closed-ended questions to a broad sample of consumers representative of the UK population. User innovation indicators were therefore included as part of a broader survey that covers a range of other topics.

Data were collected in the respondents' homes by a qualified workforce of interviewers over a two week period in May 2009. This face-to-face approach has several benefits, most importantly that interviewers are able to comment and repeat questions when respondents needed clarification. Data was obtained for 2,109 UK consumers selected through random location sampling, the best guarantee for a representative sample. Some relevant descriptive statistics on the nature of the sample are presented in Table A7.

Despite the random sampling, responses were slightly selective in the sense that elderly people, retired people and people who are not in employment are more likely to be surveyed. Their willingness to participate in face-to-face surveys is somewhat better, and more importantly, they tend to be at home during the day (when a substantial part of the survey is conducted).

The data were weighted to ensure that demographic profiles match those for all adults in the UK aged 15 or over. Weights were computed drawing on population figures as provided by UK Statistics, with target profiles set for gender, employment status, age classes, social grade and standard regions. In the current report only weighted results are presented.

Questions

The research team added five closed-ended questions to the BMRB Omnibus survey. Table A8 gives an overview of the topics that were covered.

Section A is the key part, where respondents were asked for their innovative efforts in the

Table A8: Relevant topics in the consumer screening survey

Section	Variable	Description
A. Incidence of user innovation	a01	content production
	a02	software modification
	a03	software creation
	a04	product modification
	a05	product creation
K. Other	k00	region
	k01	gender
	k02	age classes
	k03	employment status
	k04	size of household
	k05	chief income earner
	k06	educational attainment
	k07	social grade
	k08	terminal education age

past three years. More specifically, they were asked if they had produced content for the Internet (i.e. if they had shared something online that they created themselves, such as their own designs, artwork, photos, stories or videos),[41] modified software (i.e. if they had modified any computer software programs they use by making alterations in the source code), created new software from scratch (i.e. by means of programming original code), made any modifications to products (i.e. modifying any product that they use in daily life, such as tools, toys, sporting equipment, cars, household equipment etc.), and created products from scratch (i.e. to use themselves, such as tools, toys, sporting equipment, cars, household equipment etc.).

This led to the collection of data on the same types of user innovation discussed in the firm survey, plus an additional indicator concerning content production and sharing in the Internet. Section K collected data on some standard background variables that BMRB kindly added to the survey.

More detailed investigation in follow-up survey

The following indicators were constructed on the basis of these data:

- **Content production:** identical with question A01.
- **User modification:** combining A02 and A04.
- **User creation from scratch:** combining A03 and A05.
- **User innovation:** combining A02, A03, A04 and A05.

Drawing on weighted data, the initial finding was that 34 per cent of the UK consumers were producing content for the internet. In addition, 25 per cent indicated that they were user modifiers, and 15 per cent that they had created user innovations from scratch. Overall, 28 per cent of all respondents were estimated to be user innovators (modifier and/or creator).

There were some doubts about the reliability of these figures. Since only closed-ended questions had been asked, there was no way

41. This question was included in order to 'warm-up' the individuals taking part in the survey for the questions to follow.

of checking if respondents had interpreted the questions correctly. This is one of the reasons why another, much more detailed follow-up survey of UK consumers was undertaken. We focus on it now.

Consumer follow-up survey

The follow-up survey collected data on the types of user innovations that individual consumers reported in order to establish whether they were, indeed, user innovations. Another goal was to collect detailed information on consumers' expenditure on user innovation, and their networking behaviour when developing their innovations.

Sample and data collection

The methodology of the consumer follow-up survey was similar to that of the firm survey. BMG Research was once again commissioned to implement it by means of computer assisted telephone interviewing (CATI). Their telephone numbers were identified by means of a random number generator. The sample frame was not designed to be representative and the second consumer survey targeted those respondents which were most likely to be user innovators, as determined through an exploration of the consumer screening survey data.

The survey was implemented in July and August 2009. In this period BMG contacted 2,240 individuals. Responses were obtained for 344 consumers, a response rate of 15.31 per cent. Although this sample size is too small to draw any robust conclusions or to allow for comparisons between groups of consumers, it is, however, large enough to assess the quality of the initial indicators, and compute sensible correction factors to adjust the results of the consumer omnibus (see hereafter). Relevant descriptive statistics of the respondents are presented in Table A9.

The population for this survey was different from the earlier omnibus study. The sample contained a larger share of males, people in employment, and people with higher social grades. As this survey was not designed to produce representative statistics, the data was not weighted. Rather, all reported innovations were used to assess the quality of the indicators (as discussed hereafter).

Questionnaire

The questionnaire was again optimized for telephone surveying. It contained many follow-up and open-ended questions to explore the nature of the innovations reported by consumers. The relevant parts of the questionnaire are summarised in Table A10.[42]

Section A documented potential user innovations and explored their nature. In line with the previous surveys, distinctions were made between four types of innovation: software modifications, software created from scratch, product modifications, and products created from scratch. For each type of user innovation, respondents indicated if they had, in the past three years, undertaken any such innovation.

If the answer was 'yes', then a number of follow-up questions were asked, including open-ended questions to obtain full descriptions of the reported innovations, and to determine why had they been carried out. Respondents were also explicitly asked if they had developed these innovation as part of their job (rather than in their leisure time), and if they could have bought a similar product (with the same function) in the market.

42. There was also a section for respondents who reported to be no user innovators. Our idea was to explore what kept respondents from developing user innovations, but only few relevant responses could be identified.

Table A9: Distribution of respondents in consumer follow-up survey (n=344)

Variable	Values and percentages
Gender	Men (73%); Women (27%)
Age class	15-24 (9%); 25-34 (17%); 35-44 (20%); 45-54 (21%); 55-64 (21%); 65+ (12%)
Social grade	A (5%); B (38%); C1 (40%); C2 (17%); DE (0%)
Standard region	London (9%); South East (10%); South West (11%); Wales (8%); East Anglia (9%); East Midlands (9%); West Midlands (10%); Yorkshire and the Humber (8%); North West (8%); North East (8%); Scotland (10%)
Employment status	Working (85%); Not working excluding retired (5%); Retired (10%)

Table A10: Outline of consumer follow-up survey

Section	Variables	Description
A. Incidence of user innovation	a01-a06	software modification: incidence, nature, newness and motivations
	a11-a16	software creation: incidence, nature, newness and motivations
	a21-a26	product modification: incidence, nature, newness and motivations
	a31-a36	product creation: incidence, nature, newness and motivations
B. General expenditures on user innovation	b01	time investment (days)
	b02-b03	money investment (UK pounds)
	b04-b05	estimated number of user innovations
C. Networking, expenditures and protection of specific user innovations	c02-c06	involvement of other people, and nature
	c07	time investment (days)
	c08-c09	money investment (UK pounds)
	c10-c11	using methods of protection, and nature
	c12-c15	sharing the innovation, and types of compensation
K. Other	k00	region
	k01	gender
	k02	age classes
	k03	employment status
	k06	educational attainment
	k07	social grade

Sections B and C were asked only if respondents had reported at least one user innovation. In Section B, they were asked for rough estimates on how much time and money they had spent on user innovation over the past three years. They were also asked to estimate the number of innovations that they had developed (either modifications or creations from scratch). In Section C, respondents were asked to elaborate on the most recent reported innovation. This had the aim of establishing whether there had been involvement of other consumers, what the expenditures in terms of time and money had been, and whether the intellectual property over the innovations had been protected, or shared with others.

Finally, Section K contained background information such as gender, age classes, regions or social grade.

Validation

The reported cases were once again checked to detmine whether they were truly user innovations – and to exclude them from the sample if they were not. First, all cases of innovations that respondents had developed as part of their jobs we excluded, since these would not be innovations developed by individuals in their role as consumers. Also, home-built versions of products which consumers could have bought on the market were excluded. Applying these criteria led to the exclusion of about 50-60 per cent of all reported innovations. Next, two researchers examined and recoded all open-ended descriptions. Examples of reported innovations are shown in Table A11.

This validation process led to the exclusion of many survey responses. For reported software creations, 14 per cent were excluded as not

Table A11: Filtering out false positives: Examples of reported innovations and 'non-innovations' in consumer follow-up survey

Type	Judged to be a user innovation	Judged NOT a user innovation	Percentage of false positives
Software modification	'I modified my MP3 player to enable it to use SQL. I was using my own databases but they started to slow down as I added more data. I wanted to speed up the system and make it more robust.'	'I upgraded the software system, Windows upgrade. To make it compatible to the new version of games.'	43%
Software creation	'I built my own predictive analysis software, designed to provide optimized costs. It optimizes everything to do with final cost. Doing it manually takes about 4 hours, but now it takes 20 minutes with the software.'	'I created a database on my PC by using Excel to set up spreadsheets to better monitor my household expenses. I was out of a job at the time and I wanted to create this software because I knew how to and to learn more.'	14%
Product modification	'I modified a washing machine, where I changed the way the timer worked to give a spin only option. I also bridged one of the circuits and inserted a switch. Due to the weather, I wanted the washing machine to spin only.'	'I have recently upgraded my PC. I bought a new internal hard drive and upgraded the internal memory. I needed more space for the files in my computer.'	31%
Product creation	'I made an automatic dog food feeder. I used parts from a washing machine, an electric inlet and a household timer which fitted together with the feeder. It automatically loads the food. My dog has diabetes and needs to be fed in time.'	'I refurbished my old seat cushions, I used new sponge material and repaired it to be new again. As it was cheaper to repair it than to buy a new sofa.'	7%

actually being user innovations; for software modifications, 43 per cent were excluded for this reason. In the case of product creations, 7 per cent were excluded for this reason, and in the case of product modifications, 31 per cent were excluded for this reason. As can be seen, the responses about 'modification activities' were found to be particularly unreliable. Respondents found it hard to distinguish between modifying objects and simply upgrading them. This is an issue that will require attention in future survey designs.

In total, screening and recoding of the follow-up survey showed that 70 to 75 per cent of all initially reported cases were in fact not user innovations according to strict criteria. Drawing upon this result, the research team calculated correction factors to adjust the estimates of the (much broader and representative) consumer screening survey. In doing so, it was assumed that the share of false positives in the screening sample of 2,109 consumers was along the lines of the shares of false positives in the follow-up survey.

It is important to remind the reader that this is the first survey of user innovation in a broad sample of individual consumers. More survey design and testing will be needed in order to develop easier-to-use user innovation indicators for individual consumers. We do not suggest that the research procedure followed here is suitable 'as is' for application in official government surveys.

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