



MIT Sloan School of Management

MIT Sloan School Working Paper 4722-09
2/3/2009

The prevalence of user innovation and free innovation transfers:
Implications for statistical indicators and innovation policy

Fred Gault and Eric von Hippel

© 2009 Fred Gault and Eric von Hippel

All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission, provided that full credit including © notice is given to the source.

This paper also can be downloaded without charge from the
Social Science Research Network Electronic Paper Collection:
<http://ssrn.com/abstract=1337232>

**The prevalence of user innovation and free innovation transfers:
Implications for statistical indicators and innovation policy**

Fred Gault,
Visiting Fellow, International Development Research Centre, Ottawa, Canada
and
Eric von Hippel,
MIT Sloan School of Management, Cambridge, MA, USA.

January, 2009

Acknowledgements: We would like to express our appreciation to Susan Schaan of Statistics Canada for her help with the 2007 survey we report upon here. Also we thank Mark Uhrback and Jeroen de Jong for their contribution to the development of the survey questions, and thank Statistics Canada colleagues for the testing of the resulting questionnaires. Finally, we thank Joachim Henkel for his careful and critical reading of the final manuscript.

**The prevalence of user innovation and free innovation transfers:
Implications for statistical indicators and innovation policy**

ABSTRACT

Statistical indicators have not kept pace with innovation research. Today, it is well understood that many industrial and consumer products are developed by users, and that many innovations developed at private cost are freely shared. New statistical indicators will empower policymakers to take advantage of the latest research findings in their innovation policymaking, and will enable them to benefit from improved measurement of resulting policy impacts.

In this paper, we report upon a pilot project in which a novel set of statistical indicators were deployed in a 2007 survey of 1,219 Canadian manufacturing plants. The plants all developed or modified “advanced” process technologies for in-house use. Responses to the survey showed that data on both user innovation and the transfers of these innovations could be reliably collected, and that novel findings important to policymaking would result. One such finding: About 20% of the user-innovators surveyed reported transferring their innovations to other users and/or equipment suppliers – and the majority of these at least sometimes did so *at no charge* to recipients. Since cost-free sharing of innovations is understood to result in greater social welfare than licensing for a fee, innovation rates being equal, this finding has important public policy implications. Current government innovation policies tend to favor and even to subsidize the obtaining of intellectual property rights as a means of encouraging innovation. If a significant fraction of user-innovators in the economy are already freely revealing their innovations - despite the availability of intellectual property grants - perhaps intellectual property rights policies should be reexamined.

We propose that improved versions of the novel statistical indicators piloted here should be integrated into official statistics so that user innovation, and related matters such as voluntary spillovers of innovation-related information, can be better monitored, better understood, and better managed.

The prevalence of user innovation and free innovation transfers: Implications for statistical indicators and innovation policy

1. Introduction and overview

Empirical research by innovation scholars has now clearly documented that many of the innovative products we buy from producers are in fact developed and prototyped and tested and improved by “lead users.” These individuals and firms often innovate in order to solve their own, ahead-of-market needs. Later, when a commercially-attractive market emerges for these products, producers adopt or learn from products users have already developed and used in the field as an important feedstock to their own product development and commercialization efforts. This user-centered innovation pattern has been shown to hold both in the case of innovating user firms developing processes and equipment and software for in-house use, and in the case of innovative products developed for individual end users, like novel sports equipment and foods. End user “consumers,” it has been found, working individually or in groups, are the actual developers of many consumer products later commercialized and sold to the general marketplace by producers.

We define user-innovators as firms or individual consumers that benefit from *using* a product or a service they develop. In contrast, producer-innovators are firms or individuals that benefit from *selling* a product or a service they develop. Lead users are a subset of all users. Their primary distinguishing feature is that they are ahead of important market trends, and so experience new emerging needs ahead of the bulk of the market. As a result, lead users often innovate in order to solve their own, ahead-of-market needs – often before producers are even aware of those new needs (von Hippel, 1988, 2005).

Statistical indicators used in official surveys of innovation activities have not addressed this new understanding of the central role of users in the innovation process. New indicators must be created to provide a clearer picture. This is especially important as research shows that user innovation is becoming steadily *more* important due to steady improvements in Internet communication tools and computer-based design and design collaboration tools.

In this paper, we report upon a first use of novel statistical indicators in a survey measuring important aspects of user development and diffusion of innovations. This survey was undertaken by Statistics Canada in 2007, and utilized a sample of 1,219 Canadian manufacturing plants. It was required that all survey participants had developed new process equipment innovations for their own use, and/or had modified process equipment to better suit their needs.

Analysis of survey responses showed that, on average, innovating user firms had spent a significant amount of money and time developing process innovations and improvements for in-house use. Analysis also showed that about 25% of these firms knew that innovations they had developed had been adopted by process equipment producers. A similar fraction was aware that innovations they had developed had been adopted by other user firms.

When asked about the terms under which their innovations had been transferred to adopters, a significant fraction reported that they did not receive a fee or other consideration for the transfer of their intellectual property. User-innovators that had transferred their innovations without fee explained that they were motivated to do so because of expected benefits to themselves including: to allow a supplier to build a more suitable final product; to gain feedback and expertise; and, to enhance reputation. These benefits are similar to the types of benefits claimed by contributors to open source software projects – which supports the idea that the pathways to private returns from free revealing are quite general in their basic nature. As we will discuss in section 5, this finding may justify significant changes in government policy related to intellectual property rights.

We have been able to capture the innovation patterns just described because the experimental Statistics Canada survey we report upon, to be described in detail later in the paper, differs in two crucial respects from current official government surveys of the innovation process: (1) innovation *development* by users is better tracked; and, (2) the *transfer* of user-developed innovations from users to producers is tracked for the first time in any government survey. As a result, what is actually occurring among innovators and adopters in the field is more accurately captured. We think that it is important to create similar improvements in official government surveys and innovation statistics.

These improvements will enable policymakers to build their work upon more accurate assessments of real-world innovation processes. In section 5, we will explain the major improvements we think are needed, and explain our reasoning.

The remainder of this paper is organized as follows. In section 2 we review relevant scholarly literature. In section 3 we explain the methods used in the 2007 Statistics Canada follow-up survey on user innovation among Canadian manufacturing firms. In section 4 we present our findings derived from that study. In section 5, we conclude with a discussion of steps policymakers can take to better measure and assess the free revealing of innovation-related information via new statistical indicators.

Section 2: Literature Review

In this paper, we will report upon empirical work that explores the development and transfer of advanced process equipment innovations, carried out by firms that *use* that equipment. Accordingly, in this section, we first briefly review the empirical literature documenting user innovation. Next, in order to create a platform for a discussion of innovation transfer patterns observed in our survey, we discuss the nature and economics of intellectual property rights, and the economics of “free” innovation transfer. Finally, we discuss the current near-absence of government statistical indicators and surveys related to the increasingly important phenomena of user innovation and the diffusion user-developed innovations.

2.1 User Innovation

User innovation has been found to be both important and frequent in both industrial and consumer fields. In both, the most active user-innovators are the “lead users” that populate the leading edge of markets and have a strong need for solutions to the new needs they encounter there. User innovation has been extensively studied and reported upon by many, so this overview will be comparatively brief, and will focus upon what is known about user innovation in process equipment – the subject matter of the pilot study we will report upon later. A thorough review of user innovation of all types can be found in von Hippel (1988 and 2005).

Empirical studies have found that, in the great majority of fields studied, process equipment users rather than equipment producers are the actual developers of most functionally and commercially important process equipment innovations. Thus, in a combined sample covering the fields of semiconductor production equipment and printed circuit card processing equipment, 67% of the most important process machine innovations were found to have been developed by machine users (von Hippel, 1977). In the field of pultrusion processing equipment (a type of plastics processing equipment) 90% of the most important innovations were developed by users (Lionetta 1977). Enos (1962) reported that nearly all the most important innovations in oil refining processes were developed by user firms. Freeman (1968) found that the most widely licensed chemical production processes were developed by user firms. Pavitt (1984) found that a considerable fraction of inventions by British firms was for in-house use. VanderWerf (1992) studied samples of important industrial gas-using and plastics forming process equipment innovations. In both samples, users were found to be the most frequent developers of these innovations.

Extant empirical research also documents that *many* user firms develop and modify process equipment to serve their own, in-house needs. As can be seen in table 1, process innovation studies directed at specific types of process innovation have shown that a significant percentage of users do develop or modify process equipment and software for their own, in-house use.

The broadest of the studies summarized in table 1 was based upon a survey of 26 Advanced Manufacturing Technologies (AMTs) that Statistics Canada conducted in 1998 (Sabourin and Beckstead 1999). The sample for that survey consisted of Canadian manufacturing establishments with at least 10 employees. Among other questions, it collected data on the adoption, modification and development of 26 specific technologies that had been selected as advanced manufacturing technologies (AMTs) at the time of the survey – technologies such as material-cutting with the use of laser energy or water jets rather than traditionally-used physical cutting tools (Arundel and Sonntag, 1999). A key finding was that 46 percent of the surveyed manufacturers bought AMTs ‘off the shelf’ only. Twenty-six percent, however, modified the AMT equipment they purchased, and 28% developed their own specific technologies because there was no market supply.

Table 1 : Studies of frequency of process innovation by users

Innovation Area	Number and type of users sampled	% developing or modifying process equipment or software for their own use
Process Innovation Type		
Printed Circuit CAD Software (a)	136 user firm attendees at a PC-CAD conference	24.3%
Library Information System software (b)	Employees in 102 Australian libraries using computerized OPAC library information systems	26%
Medical Surgery Equipment (c)	261 surgeons working in university clinics in Germany	22%
Apache OS server software security features (d)	131 technically sophisticated Apache users (webmasters)	19.1%
26 'Advanced Manufacturing Technologies' introduced into Canadian plants (e)	Canadian manufacturing plants in 9 Manufacturing Sectors (less food processing) in Canada, 1998 (population estimates based upon a sample of 4,200)	28% developed 26% modified
Any type of process innovation or process modification (f)	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) Morrison et al. 2002, (c) Lüthje 2003, (d) Franke and von Hippel 2003, (e) Arundel and Sonntag 1999, de Jong and von Hippel 2009

In 2007, Statistics Canada conducted another survey of advanced manufacturing technology adoption and in-house modification and development (Statistics Canada 2008a). While the lists of technologies vary between the 1998 survey and that of 2007, the propensity of plants in manufacturing to use at least one of the technologies in the list has increased from 76% in 1998 to 92% in 2007. The propensity to modify or develop a technology for the same two surveys was 26% and 28% in 1998 (Arundel and Sonntag 1999) and 21% and 22% in 2007 (Schaan and Uhrback 2009). While this appears to be a declining trend, the estimate for the propensity to modify an adopted technology for the universe of manufacturing plants has remained more or less the same at 21% and 19%. It therefore appears that about 20% of manufacturing plants in Canada are adopting technologies by purchasing and modifying them, and a comparable proportion (21% and 20%) adopts by developing the technology needed in the absence of a suitable one available on the market.

2.2 Economics of intellectual property rights

The economic reasoning which has led governments to grant innovators intellectual property rights is familiar to many. It begins with the assumption that private individuals and firms will invest in innovation only if they expect to make attractive profits from doing so. If imitators can get free access to information innovators have spent money to develop, it seems reasonable that innovators' profit expectations will drop: after all, innovators will then expect to be competing in the marketplace with imitators that have lower costs because they have been able to "free ride" on innovators' investments.

Free riding is likely because information is slippery stuff. For example, it has been shown that industrial secrets generally become known to competitors after only a short while. Thus, Mansfield (1985) studied 100 American firms and found that "information concerning development decisions is generally in the hands of rivals within about 12 to 18 months, on the average, and information concerning the detailed nature and operation of a new product or process generally leaks out within about a year." Indeed research shows, perhaps as a consequence of such pervasive and rapid information spillovers, that social rates of return on innovation are higher than private rates of return. This in turn implies that private rates of return should somehow be increased so that society gets "enough" innovation.

There are many ways to increase innovators' private returns from innovation to compensate for the effects of free riding by imitators. For example, governments can and do offer R&D subsidies and tax credits to lower innovators' private costs. Governments also can and do enhance innovators' private returns by granting those who qualify temporary monopolies on their innovation-related knowledge via intellectual property law. Indeed, in the U.S., the power to grant such monopolies is grounded in the Constitution (Article I, Section 8, Clause 8), which empowers the United States Congress: "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." So empowered, the Congress of the United States, along with the governments of essentially every nation in the world, have instituted systems of patent and copyright grants to serve this end.

Of course, economists and policymakers understand that encouraging innovators by granting even temporary monopoly rights to specific information, usually creates significant economic costs that society must bear. Innovators' routes to increased profits involve restricting access to and/or charging fees for utilizing their protected information. This information would otherwise be free and universally available – because information today is reproducible at a marginal cost close to zero. The result is the creation of what is called a “deadweight loss” to the economy: Patent and copyright owners can charge more than they could if access to the information was free. Also, additional applications of the information that would pay only if access were free are not undertaken – and this creates further economic loss. (An offsetting factor by which intellectual property rights may act to reduce deadweight loss is that innovators may disclose more if they are granted temporary monopoly rights to their knowledge – and a temporary secret is better than a permanent one in terms of social welfare. However, as we noted earlier, it is difficult to keep a secret for long in any case, and so the extent of this proposed advantage is not clear.)

2.3 Economics of free revealing

When we say that an innovator “freely reveals” proprietary information, we mean that the information is opened to others at no cost, and all parties are given equal access to it—the information becomes a public good (Harhoff, Henkel, and von Hippel 2003). Until the economics of free revealing began to be understood and appreciated, the losses associated with intellectual property rights had seemed a necessary evil to both academics and policymakers, for reasons described earlier. Debates about the intellectual property system, therefore, did not deal much with its fundamental desirability. Instead they were largely restricted to the desirability of various refinements to the system, such as increasing or decreasing patent quality, and decreasing or increasing the length of a copyright grant.

An appreciation of the economics of voluntary free revealing has now changed the terms of this debate – because free revealing also encourages innovation through private rewards, but does this without public grants of temporary legal monopolies to innovators.

The phenomenon of free revealing of innovations has been brewing in the backwaters of economics for quite some time. Routine and intentional spillovers of innovation-related knowledge developed by profit-seeking firms at private expense was first described by Allen (1983). He reported upon what he called collective invention in historical records from the nineteenth-century English iron industry. In that industry, Allen noted the surprising fact that employees of competing firms routinely publicly revealed information on their privately-developed innovative furnace design improvements and related performance data in meetings of professional societies and in published material.

After Allen's initial observation, a number of other authors searched for voluntary, intentional knowledge spillovers among profit-seeking firms and frequently found it. Nuvolari (2004) found similar voluntary spillovers in the early history of mine pumping engines. Contemporary voluntary spillovers by users have been documented by von Hippel and Finkelstein (1979) for medical equipment, by Lim (2000) for semiconductor process equipment, by Morrison, Roberts, and von Hippel (2003) for library information systems, and by Franke and Shah (2003) for sporting equipment. Henkel (2006) has documented free revealing among producers in the case of embedded Linux software.

More general interest in the phenomenon of free revealing was sparked by the emergence of "open source" software development projects into public prominence in the 1990's. Clearly, it seemed to observers, open source software was a phenomenon of major economic importance. And, in the many open source software projects using the popular General Public License (GPL), it was enforced *policy* that project contributors would routinely and systematically freely reveal the software code they had developed at private expense to an information commons (Stallman 1998)

Research into why innovators would freely reveal their innovations at no charge taught us how the behavior could be economically rational. Innovators could profit from their private innovation investments despite or even because of their voluntary information spillovers. Routes to private profit through free revealing of innovations were found to include increases in innovators' reputations, which in turn increase the profitability of innovating firms (Allen 1983) or the job prospects of individual contributors (Lerner and Tirole 2002). Also, innovators granting costless access to their

innovations usually increase the diffusion of that innovation relative to what would occur if they charged fees for access. Increased diffusion, in turn, often increases the value of that innovation to the innovator via what are called network effects. (The classic example: the greater the number of people who adopt telephones, the greater value the telephone has for each owner: after all, there are more people to call.) It has also been learned by experience that innovators freely revealing their innovations often get valuable feedback and improvement suggestions and designs from adopters (Raymond 1999). Further, adopting manufacturers may be able to produce the innovation and sell it at a price lower than innovating users' in-house production costs – which provides a benefit to those innovating users (Harhoff et al, 2003).

Finally, individual participants in open and collaborative innovation projects, such as open source software development projects, say they derive valuable private benefits from the fun and learning they gain from participation (Lakhani and Wolf 2005).

Any and all of these consequences of free revealing just described can produce significant private returns to the original user-innovator. The net result is a new appreciation of how innovators can actually profit by “giving away” innovations they develop at private expense.

2.4 Measuring conditions of innovation transfer

Innovation transfers from user-innovators to producers, and the terms under which these take place, are today *not measured* by any indicators used in official statistics. Existing surveys that come closest – but not very close - are the Community Innovation Surveys (CIS). The CIS are coordinated by Eurostat and carried out by members of the European Union, and some other countries. An example is the third CIS (Eurostat 2004). The 2005 Canadian Innovation Survey (Statistics Canada 2005, 2006) is close to the CIS model.

CIS surveys are addressed to firms. One question offers a list of possible information sources ranging from “clients” to suppliers to government labs, and asks respondents to rate the importance of inputs from each to their development efforts for their innovation projects. Invariably the client (user) is ranked as supplying very important information by most (Eurostat 2004:56).

This question poses two problems from the point of view of documenting the innovation role of users. First, it does not ask about the actual nature of the information transferred from user to producer. This is a problem, because such information can range from very rich – for example, a CAD file containing the entire, field-tested design for a new product, to information as sparse as “I need an updated machine from you.” Second, respondents are not asked about the *terms* under which this ‘very important information’ was supplied. If, for example, a user offered information of substantial value to the producer, such as a complete prototyped and field-tested design, was that information licensed to the producer for a royalty? Or, was it provided gratis as in the free transfer pattern described earlier?

2.5 A companion study

A study by de Jong and von Hippel (2009) can be regarded as a companion to the empirical research we report upon in this paper. That study also explores innovation and innovation transfer by user-developers of process innovation. It is based upon a sample of 498 “technology-based” firms in the Netherlands with 100 or less employees.

In brief overview, the de Jong von Hippel study found that 47% of respondents reported developing entirely novel process equipment for their own use. The average project cost was €235 000. Thirty six percent of respondents reported modifying their process equipment at an average project cost of €120 000. These are quite significant investments for these relatively small firms. Yet, only 13% of these projects were protected by any form of intellectual property by the user-innovators.

With respect to information transfers from innovators to others, 25% of the user innovations were transferred to process equipment producers that presumably manufactured them for general sale. Forty eight percent of these were simply given away to these producers without compensation, and a further 39% were transferred with only informal offers of possible future compensation by recipient producers, such as possible price reductions on future purchases.

3. Survey methods

The survey data from which we draw our findings (Statistics Canada 2007b) were collected by a follow-up survey addressed to a sample of user innovator firms identified by the Statistics Canada Survey of Advanced Technology 2007 (AT07 Survey). The sample for the AT07 Survey was drawn from Statistics Canada's Business Register (June 2007 version) during July 2007 from a population of 16,590 manufacturing establishments and 622 logging establishments that met the criteria of having at least \$250,000 in revenues, and at least 20 employees. The sample of about 9,250 establishments in scope for the survey, and a response rate of 72.8%, gave rise to completed questionnaires for 6733 establishments.

Respondents to the Statistics Canada Survey of Advanced Technology 2007 were asked whether they had adopted any of a list of 26 specific Advanced Manufacturing Technologies (AMTs) as part of their manufacturing processes. (An example of such an AMT would be the cutting or shaping materials via the use of laser light rather than via the physical cutting tools traditionally employed for cutting and shaping.) Those who reported adopting one or more AMTs were then asked whether they had: (a) significantly modified one or more AMT process equipment types to better suit their production needs; or (b) whether they had developed entirely new equipment within one of the 26 AMT categories within the last 3 years. All answering "Yes" to either (a) and/or (b) were asked to participate in a follow-up to the AT07 Survey conducted by Statistics Canada. The authors of this paper participated in the development of the questions related to respondents' innovation activities used in this follow-up survey.

Each firm that identified itself as a process innovator received one of two follow-up questionnaires (Schaan and Uhrbach 2009). Firms that had modified one or more AMTs to better suit in-house needs received a questionnaire pertaining to the modification of technologies. Those indicating that they developed new AMT-related technologies and those who indicated they both developed new technologies and had done modifications were sent a questionnaire pertaining to their development of new technologies for in-house use. Completed surveys were obtained from 1,219 establishments, 618 dealing with in-house modifications, and 601 with new AMT-related technologies developed in-house. Unlike the AT07 Survey which provided estimates for

the manufacturing plants based on a statistical sample, the follow-up survey was an unweighted quota sample. Response rates to individual questions were all in the high 90% range, with the exception of questions about innovation project costs, where the response rates were in the high 80% range.ⁱ

4. Survey findings

4.1 Extent and cost of process innovation by Canadian user firms

Selection criteria for the 2007 Follow-up to the AT07 Survey insured that *all* respondents had modified and/or developed new process equipment related to one or more of 26 AMTs they had adopted within the last 3 years. As we see from table 2, a significant fraction of respondents report engaging in these activities on a continuing basis, and most do this through informal programs.

Table 2: What was the nature and extent of user innovation programs?

Responses from innovators that → Modify existing technologies Develop new technologies

Q1. How frequently is the modification (development) of technologies carried out in your business unit?

Continuously	35.3%	50.0%
Occasionally	64.7%	50.0%
Total follow-up survey sample	100%	100%

Q2. How is the modification (development) of technologies carried out in your business unit?

Formal Program	20.1%	36.5%
Informal Program	79.9%	63.5%
Total follow-up survey sample	100%	100%

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

We next see from table 3 that the average user project to modify or develop AMT-related process equipment involves a substantial expenditure of cost and time. The average modification project cost over \$600 thousand Canadian, and took in excess of 2 months to execute. The average new technology development project cost almost \$1 million Canadian, and took in excess of 6 months to execute.

Table 3: What were the costs of user innovation projects?

<i>Responses from innovators that →</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q14. The average cost of labor (for the most recently modified or newly-developed technology)</i>	\$228,604	\$427,863
<i>The median value of cost of labor (for the most recently modified or newly-developed technology)</i>	\$20,000	\$77,123
<i>Q15. The average cost of machinery (for the most recently modified or newly-developed technology)</i>	\$405,564	567,966
<i>median value for cost of machinery</i>	\$40,000	75,000
<i>Q16. The elapsed time required to complete the project (for the most recently modified or newly-developed technology)</i>		
5 days or less	10.0%	2.7
6 to 30 days	15.9	3.4
from 1 month to 2 months	11.6	3.5
from 2 months to 6 months	22.2	17.0
from 6 months to 1 year	21.7	25.0
from 1 year to less than 2 years	14.1	30.5
from 2 years to less than 5 years	4.3	15.8
more than 5 years	0.2	2.1

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

Resources expended on process innovation projects come largely from the innovating firms themselves. As can be seen from table 4, 98% of these projects are funded entirely or partially from internal process user firm funds. Some also involve investments from customers, from suppliers or from “other” funding sources.

Table 4: What were the sources of funding for user innovation projects?

<i>Responses from innovators that →</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q3. How is the modification (development) of technologies funded in your business unit?</i>		
Internally	98.0	98.3
By customers	7.8	16.8
From other funding sources	6.5	11.2
By suppliers	5.9	13.0

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

At the same time, more than half of respondents report cooperating with others to carry out their innovation projects (table 5). We do not know the source of funds drawn upon by other cooperators during the innovation projects in which they mutually engage.

Table 5: Did user-innovators share the development work with others?

<i>Responses from innovators that →</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q6. Does your business cooperate with other business units, firms or institutions to modify (develop) technologies?</i>		
Yes	55.5	65.1
No	44.5	34.9
<i>Q7. Who did your business cooperate with for the modification (development) of technologies?</i>		
Suppliers	85.5	82.2
Other business units in firm	57.8	51.4
Consultants	41.6	40.5
Clients	34.5	52.0
Industrial associations	15.6	18.0
Universities	12.7	30.8
Commercial labs	10.6	21.9
Competitors	8.8	12.5
Federal government labs	5.9	13.8
Colleges	5.6	11.5
Provincial labs	2.4	6.3
Private non-profit	1.2	4.7
Other type	0.6	1.8

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

As a final element in this section, we report upon responses to a question on the type of budget used for the user process innovation projects. As can be seen, about one half of the development projects and one third of the maintenance projects are funded as R&D (table 6).

Table 6: What types of budgets were used for user innovation projects?

<i>Responses from innovators that →</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q4. Which budgets are used for technology modification (development) in your business unit?</i>		
Part of the maintenance budget	52.3	32.6
Dedicated budget for each project	51.9	48.4
Part of the R&D budget	32.4	53.9
Other budget	12.3	15.3
Part of the innovation budget	10.7	10.5

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

4.2: Protection of and diffusion of user-developed process innovations

We now turn to a second major category of findings – how user process innovation is protected and/or diffused. From table 6, we can see that only about half of the user-innovator respondents attempt to protect their process innovations from potential imitators in any way. Since fewer modification projects are protected than are new development projects (which, as we saw in table 3, are on average more expensive) it may be that there is some tendency to protect more expensive projects – and/or it may be that intellectual property protection is easier to obtain on the more novel projects.

The responses in table 7 regarding methods of protection employed add up to more than 100% since many respondents use more than one method. The confidentiality agreement, which is relatively cheap, is the protection methodology most utilized by respondents. Such agreements are generally only negotiated with specific firms seeking to inspect specific innovations. This suggests that a lot of the process innovations developed by user-innovator manufacturing firms are in fact of interest to and examined by others outside the firm.

Table 7: How were user-developed innovations protected?

<i>Responses from innovators that →</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q11. Does your business unit use any method to protect your process IP?</i>		
Yes	46.4	60.3
No	53.6	39.7
<i>12. If yes, how do you protect your IP?</i>		
Confidentiality agreements	81.0	85.7
Patents	48.9	64.0
Secrecy	41.5	47.2
Trademarks	29.6	39.9
Copyrights	14.4	22.2
Other	1.1	2.5

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

In table 8 we see that about 40% of firms know of other firms that have carried out developments similar to theirs – so there is certainly a significant amount of independent parallel invention and/or collaborative development going on among users.

Table 8: Were user-innovators aware of others developing similar innovations?

<i>Responses from innovators that</i>	<i>→ Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q5. Do you know of other firms that have carried out (developments) similar to yours?</i>		
Yes	38.0	44.2
No	62.0	55.8

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

There is also evidence for diffusion of the user-developed innovations from the innovators in our sample to imitators. In table 9, we see that over 25% of the user-innovator firms think that, in at least one instance, a process innovation they developed for in-house use has been adopted by a supplier or other of the type of process technology at issue. Of course, “adoption” by a supplier means commercialization. With commercialization, the user-developed innovation becomes available to the entire marketplace of users.

Table 9: Were user-developed process innovations diffused?

<i>Responses from innovators that</i>	<i>→ Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q13. To the best of your knowledge, have any of the technology modifications (developments) in your business unit been adopted by the following:</i>		

Supplier of the original technology	25.2	27.4
Other firms that use the original technology	23.9	26.8

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

Table 10 provides information on the frequency and terms of innovation sharing by user-innovators. Seventeen percent of users developing process modifications, and 19% developing new process technologies, reported sharing their innovations with others. Very importantly, most of those that do report sharing say that they do this *at no charge* – in other words, their sharing is a voluntary spillover of valuable proprietary knowledge.

The reasons user-innovators give for sharing their innovations at no charge show that this is not a charitable action. Innovators expect private innovation-related returns from their sharing that that are very similar to the forms of private benefits obtained by contributors to open source software projects. For example, most expect equipment suppliers will use that knowledge to build equipment more suitable to their needs. This is a very valuable private return garnered as a consequence of sharing.

Table 10: Did users share their process innovations? Under what terms?

<i>Responses from innovators that</i>	<i>Modify existing technologies</i>	<i>Develop new technologies</i>
<i>Q8. Does your business unit share the technologies that it has modified (developed) with other firms or institutions?</i>		
Yes	17.3	19.0
No	82.7	81.0
<i>Q9. How does your business unit share the technologies it has modified (developed)?</i>		
At no charge	75.0	46.9
In exchange for something of value (i.e., free equipment)	16.0	26.5
Other method	14.0	17.7
For a fee	13.0	39.8
<i>Q10. Why did your business unit choose to share the technologies that it modified (developed)?</i>		
To allow a supplier to build a more suitable final product	53.9	53.1
Gain feedback and expertise	41.2	47.8
Nothing to lose (no direct competition)	36.3	26.5
Enhance reputation	35.3	46.0
Other	15.7	15.0
Contractual obligation	14.7	28.3

Data Source: Statistics Canada follow-up to the Survey of Advanced Technology, 2007

5. Discussion

From prior research, it is known that manufacturing firms frequently develop and improve the processes, equipment and software that they use for production. From the findings of the pilot survey of this type of innovation activity among Canadian manufacturing plants, we were able to show that a significant amount of money and time is expended on this activity – and that these innovations are a significant feedstock of process innovations for equipment producing firms.

The data also enables us to estimate that spending on process innovations by user firms is a significant fraction of all Canadian R&D expenditures in manufacturing. Based on the average expenditures in Table 2, and the fraction of Canadian manufacturing establishments represented in the survey sample, and the percentage of the expenditure which can be attributed to a R&D budget (Table 6) we find that as much as 10% of the total expenditure of \$8.3 billion made by Canadian manufacturing firms on the

performance of R&D (Statistics Canada 2008c, Table 1.17) can be attributed to process equipment innovation by user firms related only to the 26 advanced manufacturing technologies covered by the Advanced Technology Survey 2007.

Analysis also showed that about 25% of firms that developed or modified their process technologies were aware of innovations that they had developed that had been adopted by process equipment producers. A similar fraction was aware of innovations they had developed that had been adopted by other firms using similar process technologies.

When asked about the terms under which these transfers had been accomplished, a significant fraction reported that the transfers had been made without compensation through a fee or other consideration for the transfer of the intellectual property they had developed. We will discuss the important policy implications of this finding later in this section.

5.1 Types of new indicators needed

We have been able to capture user innovation and transfer pattern via the follow-up survey to AT07, because that survey differs in two crucial respects from current official surveys of the innovation process: (1) innovation *development* by users is better tracked; (2) the *transfer* of user-developed innovations from users to producers is tracked for the first time. As a result, what is actually occurring among innovators and adopters in the field is more accurately captured.

The indicators we present in Tables 2 through 10 are pilot versions of a set of new statistical indicators which could be used with respect both to monitoring the development of intellectual property, and with respect to monitoring technology transfer. We think that it is important to create similar improvements in indicators used in official surveys of innovation. Such improvements will enable policymakers to build their work upon more accurate assessments of real-world innovation processes.

In the research presented here, the new indicators were applied as part of a technology use survey. There is also a case for measuring user-developed innovation in the more prevalent innovation surveys. This could easily be done by adding questions, or by doing a follow up survey directed only to respondents reporting such activities. More

specific questions about the source of product innovations, already discussed in this paper, could be added to identify the production of products that result from user-developed innovation.

The *transfer* of user innovations to producer firms should be a matter of interest to policymakers because, as mentioned previously, we now understand that users are the actual developers of prototype versions of many of the new products introduced to the marketplace by commercial producers. Until relatively recently, researchers and policymakers did not know that significant transfers of innovation-related information from users to producers existed. Now that this is better understood, official statistical indicators and surveys may be revised to reflect this new understanding.

5.2 Example of new innovation process insights

As illustration of the important information that user innovation and innovation transfer surveys can bring to researchers and policymakers, note that the Statistics Canada pilot study has documented *two* commonly-used mechanisms by which user-innovators obtain private rewards for the transfer of their privately-funded process innovations – one involving cost-free revealing of the innovations and one not. Both mechanisms clearly offer private returns to innovators and thus encourage innovation. Free revealing has been amply documented in studies of open source software projects. It is here, and also by de Jong and von Hippel (2009), shown to be significant among user-developers of process equipment innovations for the first time. We predict that further government surveys of the type piloted here will find similar patterns of free revealing in many other industries.

From the point of view of policymakers, there are two major next questions to ask before the policy implications of this finding can be assessed: (1) are both mechanisms equally effective at inducing innovations? And (2) is one mechanism preferable to the other for some reason such as likely impacts upon social welfare? At this point, we have only initial answers to both questions. But, we will argue that these matters are so important to innovation policymaking that there is a strong case for developing the new statistical indicators needed to develop better answers over time.

First, are free innovation transfers as good as access restrictions and/or for-fee

transfers at encouraging innovation by providing access to attractive private profits? On the basis of this first survey with its novel indicators, this seems possible. Consider that it is likely that *both* fee free and fee-based transfer options are available to many of the user-innovators developing process innovations in our sample. After all, at least trade secrecy protection is always applicable in the case of process innovations that can be used by user-innovators while hidden behind factory walls. And, as we saw in Table 7, most innovators that protected their innovations did utilize trade secrecy protections – as evidenced by the widespread use of non-disclosure agreements. Yet, despite the availability of this and probably other intellectual property mechanisms to support exclusivity and the ability to charge fees for access, about half of the survey respondents choose to transfer their innovations at no fee at least part of the time. Given economic rationality on the part of respondents, this suggests that, some significant fraction of the time, innovators think that free transfer gives them greater private returns than does utilizing the monopoly rights enabled by the intellectual property rights system.

With respect to the second question, as was mentioned earlier, fee-free transfers of innovation-related information are in principle preferable to transfers involving fees or other restrictions from the standpoint of social welfare. If one charges a price for something that exceeds the marginal cost of production, one is creating a “deadweight loss.” Charging anything for information – as all innovators do who report charging a fee in table 10 – inevitably creates a deadweight loss. After all, the marginal cost of production of copies of innovation-related information today is essentially zero for most innovations.

Of course, our argument is not that intellectual property based systems should be eliminated – there are probably cases where each system is preferable to the other. Indeed, the two systems can even be used simultaneously in a synergistic way. For example, people use their copyrights to create a legal basis for offering explicit types of free access rights to others both in the case of open source software licenses and creative commons licenses (O’Mahoney 2003).

5.3 Example of new policy options

If free transfers of innovation-related information are indeed social welfare increasing relative to monopoly control over such information at least some of the time, an important question for policymakers then immediately emerges: Are government policies currently at least even-handed with respect to these two mechanisms? Or are government policies and programs in net encouraging innovators to charge fees or to restrict innovation transfers rather than engaging in more open behavior? We suspect the latter is the case.

Government certainly is making it more feasible for innovators to either maintain exclusivity in the use of their innovation or to sell it for a fee. As was discussed earlier, that is the whole purpose of the quite elaborate intellectual property rights systems established and funded with taxpayer dollars by governments world-wide. Government agencies also encourage use of this option in many subtle and not-so-subtle ways – driven by the explicit or implicit assumption that protection promotes innovation. For example, departments of the US government allow – one might even say encourage - firms and individuals to retain title to inventions developed with government funds, in order to ‘promote commercialization of federally funded inventions’. Thus, recipients of NIH grants (grantees) are instructed as follows:

“As long as grantees abide by the provisions of the Bayh-Dole Act, as amended by the Technology Transfer Commercialization Act of 2000 (P.L. 106-404), and 37 CFR Part 401, they have the right to retain title to any invention conceived or first actually reduced to practice using NIH grant funds. The principal objectives of these laws and the implementing regulation are to promote commercialization of federally funded inventions, while ensuring that inventions are used in a manner that promotes free competition and enterprise without unduly encumbering future research and discovery.” (NIH 2003)

This bias is pervasive. For example, the U.S. government funds various types of business assistance programs that invariably teach that acquiring intellectual property rights is the sensible, business-like thing to do. Consider advice given by SCORE, a non-profit business advisory organization funded by the U.S. Small Business Administration (SBA).

5 Tips on Patents 1. If your company has an invention that you think is patentable, take steps at once. You may lose your right to patent it if you offer it for sale or disclose it publicly without patent protection. (SCORE 2008)

The roots of this apparent bias in favor of intellectual property rights vs. free revealing is certainly understandable – the path towards private innovation rewards involving free revealing was not appreciated by many until quite recently. But once the free-revealing option is understood, policymakers can take steps to offset any existing biases. Three examples:

- Intellectual property rights grants can be used as the basis for licenses that help keep innovation open as well as keep it closed (O’Mahoney 2003). Policymakers can add support of “open licensing” infrastructures such as the Creative Commons license for writings, and the General Public License for open source software code, to the tasks of existing intellectual property offices. They can also encourage “defensive publishing” as a mechanism to insure that user-innovators not seeking formal IP protection for themselves cannot be excluded from using their own inventions by others at a later point. (Henkel and Pangerl 2008)
- Collaborative innovation among multiple problem-solvers increases the private returns to free revealing (Baldwin and Clark 2006). Government can establish policies that help enable and support the “the roads of the Internet Age” in the form of low-cost high bandwidth universal connectivity, open standards for joint problem-solving and so on.
- Policymakers could contemplate encouraging free revealing of innovations by user-innovators. It could, for example, institute a system of tax credits analogous to R&D tax credits for innovators that freely reveal well-documented results of their private innovation developments. Documentation might take a form analogous to a patent disclosure, vetted for novelty by patent office examiners.

5.4 Suggestions for further research

With respect to indicator development, the Statistics Canada AT07 follow-up survey was only a first step in what we think needs to be done. The pilot survey did ask user-innovators about their innovations *and* about their transfers of innovations to producers and other users. The questions asked in this pilot work seem robust – where similar questions were asked in a survey of Dutch SMEs, (de Jong and von Hippel 2009), similar results were obtained. However, much more detail is required. For example, on the basis of the questions asked in the pilot study we do not know the *extent* of the

openness of the innovators that reported sharing without a fee. Did they share their innovation-related information with everyone – which would be full free revealing – or did they only share selectively with the adopting party.

More generally, we think new indicators should explore innovation-related activities at process user sites, both with respect to innovation-related investment and innovation-related diffusion activities. Also, process innovation activity indicators directed to producer firms, such as the information sources questions in CIS-type surveys, should be adjusted to better capture the flow of innovation-related information and the terms under which it has been acquired from users. In that way, data on both sides of user-producer innovation transactions can be documented. Work by de Jong and von Hippel (2009) has shown the value of data collection from participants in both sides of such transactions.

Indicators of user developed innovation and innovation transfer practices should not be limited to process innovation in manufacturing establishments, which has been used here to demonstrate their utility. It should be extended to include many other important fields such as information and communication technologies (ICTs), and bio- and nano-technologies. As well, user developed innovation need not be limited to technologies but could also include management practices, and the development of content in ICT applications.

Further, the development of social surveys to cover the development of *consumer goods* by users is required. Development of innovations by individual end users of consumer products are currently not tracked at all in official statistics. The reason is twofold. First, it was not known until recently that there was any significant activity of this type that merited tracking. It is only now understood that lead user “consumers” are the actual developers of many consumer products, ranging from sports equipment to new foods, that are later commercialized by consumer goods producer firms (e.g., Shah 2000, Lüthje et al 2005, Baldwin et al 2006). Second, given the definition of innovation in the Oslo Manual (OECD/Eurostat 2005), the activity of innovation only happens when there is a connection to the market. In other words, an innovation developed by and consumed by end users is not officially an innovation – even if it spreads widely among users by peer to peer diffusion - unless and until it becomes an offering to the market of a new or

significantly improved product (good or service, or a mix of both). For this reason, new product development of consumer goods by producers has been tracked, while development of consumer goods by end users – very visible in some fields – has been ignored. This suggests that new indicators and social surveys be developed so that researchers and policymakers can for the first time track this important activity.

The significant evidence now available on these topics can be a useful input to discussions leading to the next revision of the Oslo Manual regarding development, and non-market peer-to-peer diffusion, of innovations by end users. This work also coincides with the development of the OECD Innovation Strategy (Gault and Huttner 2008) and is intended to contribute to the debate leading to the final report in 2010.

In order to maximize the value of these new indicators for policy purposes, they should be incorporated into technology use surveys that recur regularly and their use should be standardized in order to support international comparisons, at least across OECD countries. The repetition of the measurement and the international comparisons would support the monitoring and evaluation of policy interventions.

References

- Allen, R. C. (1983). "Collective Invention." *Journal of Economic Behavior and Organization* 4(1): 1-24.
- Arundel, Anthony and Viki Sonntag (1999), Patterns of Advanced Manufacturing Technology (AMT) Use in Canadian Manufacturing: 1998 AMT Survey Results, Catalogue No. 88F0017MIE, No. 12, Ottawa: Statistics Canada.
- Baldwin, Carliss Y. and Kim B. Clark (2006) "The Architecture of Participation: Does Code Architecture Mitigate Free Riding in the Open Source Development Model?" *Management Science* Vol 52, No. 7, (July) pp. 1116-1127.
- Baldwin, Carliss Y., Christoph Hiennerth and Eric von Hippel (2006) "How user innovations become commercial products: a theoretical investigation and case study" *Research Policy*, Vol 35 No. 9 (November) pp. 1291-1313
- Ducharme, L.M. and Fred Gault (1992), Surveys of Manufacturing Technology, *Science and Public Policy*, 19, 393-399.
- Enos, J. L., (1962) *Petroleum Progress and Profits: A History of Process Innovation*, Cambridge, MA: MIT Press

- Eurostat (2004), *Innovation in Europe: Results for the EU, Iceland and Norway*, Luxembourg: European Communities.
- Franke, N. and S. Shah (2003). "How Communities Support Innovative Activities: An Exploration of Assistance and Sharing Among End-Users." *Research Policy* 32(1): 157-178.
- Franke, N. and Eric von Hippel (2003), Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software, *Research Policy* 32, no.7, 1199-1215.
- Freeman, C., (1968), "Chemical Process Plant: Innovation and the World Market," *National Institute Economic Review* 45 (August), 29-57.
- Gault, Fred and Susanne Huttner, Commentary: A Cat's Cradle for Policy, *Nature*, Vol. 455, 462-463, 2008.
- Harhoff, Dietmar, Joachim Henkel and Eric von Hippel (2003) "Profiting from voluntary information spillovers: How users benefit from freely revealing their innovations," *Research Policy* vol 32, No.10 (December) pp.1753-1769
- Henkel, Joachim and Stefanie Pangerl (2008) "Defensive Publishing: An Empirical Study" (May). Working Paper, Technical University of Munich
- Henkel, J. (2006). "Selective Revealing in Open Innovation Processes: The case of Embedded Linux." *Research Policy* 35(7), 965–969.
- Henkel, Joachim and Eric von Hippel (2005) "Welfare Implications of User Innovation," *Journal of Technology Transfer* Vol 30 Nos. 1-2 (January) Pages 73-87.
- Herstatt, C. and E. von Hippel (1992), From Experience Developing New Product Concepts via the Lead User Method, *Journal of Product Innovation Management* 9, no.3, 213-222.
- de Jong, Jeroen and Eric von Hippel (2009) "Free Transfer of User-Developed Process Innovations to Producers: A typical behavior among Dutch High-Tech SMEs" *forthcoming*
- Lakhani, K. R. and B. Wolf (2005). "Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open Source Software Projects." In: J. Feller, B. Fitzgerald, S. Hissam, and K.R. Lakhani (eds.), *Perspectives on Free and Open Source Software*. Cambridge, MA: MIT Press.
- Lerner, J. and J. Tirole (2002). "Some Simple Economics of Open Source." *Journal of Industrial Economics* 50(2): 197-234.
- Lim, K. (2000), "The Many Faces of Absorbitive Capacity: Spillovers of Copper Interconnect Technology for Semiconductor Chips," MIT Sloan School of Management Working paper # 4110.
- Lionetta, William G., Jr. (1977) "Sources of Innovation Within the Pultrusion Industry." Unpublished S.M. thesis, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA.

- Lüthje, C. (2003). "Customers as Co-Inventors: An Empirical Analysis of the Antecedents of Customer-Driven Innovations in the Field of Medical Equipment." *Proceedings from the 32th EMAC Conference 2003*, Glasgow.
- Lüthje, Christian, Cornelius Herstatt and Eric von Hippel (2005), "User-innovators and "local" information: The case of mountain biking," *Research Policy*, Vol 34, No. 6 (August) pp. 951-965.
- Mansfield, E. (1985). "How Rapidly Does New Industrial Technology Leak Out?," *Journal of Industrial Economics*. Vol. 34, pp. 217-223.
- Morrison, P.D, J.H. Roberts and E. von Hippel (2002), Determinants of user Innovation and Innovation Sharing in a Local Market, *Management Science* 46, no. 12, 1513-1527.
- NIH Grants Policy Statement (12/03) Part II: Terms and Conditions of NIH Grant Awards Subpart A: General -- File 4 of 5, Office of Extramural Research, National Institutes of Health, U.S. Department of Health and Human Services
http://grants.nih.gov/grants/policy/nihgps_2003/NIHGPS_Part7.htm#_Toc54600131
- O'Mahony, Siobhán (2003) "Guarding the commons: how community managed software projects protect their work" *Research Policy* Volume 32, Issue 7 (July) Pages 1179-1198
- OECD (1992), OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data – Oslo Manual, OCDE/GD (92)26, Paris: OECD.
- OECD/Eurostat (1997), Proposed Guidelines for Collecting and Interpreting Technological Innovation Data – Oslo Manual (2nd edition), Paris and Luxembourg: OECD and Eurostat.
- OECD/Eurostat (2005), Oslo Manual, Guidelines for Collecting and Interpreting Innovation Data (3rd edition), Paris and Luxembourg: OECD and Eurostat.
- Pavitt, Keith. "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory." *Research Policy* 13, no.6 (December 1984): 343-73.
- Raymond, E. (1999). *The Cathedral and the Bazaar: Musings on Linux and Open Source by an accidental revolutionary*. Sebastopol, CA.: O'Reilly.
- Riggs, W. and E. von Hippel (1994), Incentives to innovate and the Sources of Innovation: The Case of Scientific Instruments, *Research Policy* 23, no. 4, 459-469.
- Sabourin, D. and D. Beckstead (1999), Technology Adoption in Canadian Manufacturing, Catalogue No. 88F0006XPB, No. 05, Ottawa: Statistics Canada
- Schaan, Susan and Mark Uhrbach (2009) "Measuring User Innovation in Canadian Manufacturing, 2007" Working Paper, Ottawa: Statistics Canada
- SCORE "5 Tips on Patents," http://www.score.org/5_tips_leg_8.html (accessed 1-2008)
- Shah, S. (2000). "Sources and Patterns of Innovation in a Consumer Products Field: Innovations in Sporting Equipment." *MIT Sloan School of Management*. Working paper # 4105.

Stallman, Richard (1998) "The GNU Project" <http://www.indymedia.org.uk/en/2004/05/292609.html>

Statistics Canada (1987), Survey of Manufacturing Technology – June 1987, The Daily, 15 October 1987, Ottawa: Statistics Canada.

Statistics Canada (1989), Survey of Manufacturing Technology – The Characteristics of the Plants, Science Statistics, Vol. 13, No.10, Catalogue 88-001, Ottawa: Statistics Canada.

Statistics Canada (2005), Survey of Innovation 2005, http://www.statcan.ca/english/sdds/instrument/4218_Q1_V5_E.pdf accessed April 24, 2007.

Statistics Canada (2006), Survey of Innovation 2005, The Daily, June 6, 2006, Ottawa: Statistics Canada.

Statistics Canada (2008a), Survey of Advanced Technology 2007, The Daily, June 26, 2008, Ottawa: Statistics Canada.

Statistics Canada (2008b), Follow-Up to the Survey of Advanced Technology 2007, The Daily, October 27, 2008, Ottawa: Statistics Canada.

Statistics Canada (2008c), Industrial Research and Development Intentions 2007, Catalogue 88-202-X, Ottawa: Statistics Canada.

Urban, G.L. and E. von Hippel (1988), Lead User Analyses for the Development of New Industrial Products, *Management Science* 34, no. 5, 569-582.

U.S. Department of Commerce (1989), Manufacturing Technology 1988, Current Industrial Reports, Washington D.C.: U.S. Department of Commerce.

VanderWerf, Pieter A. (1992) "Explaining downstream innovation by commodity suppliers with expected innovation benefit." *Research Policy* 21 315-333.

von Hippel, Eric (1977) "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation," *IEEE Transactions on Engineering Management* EM-24, no. 2 (May):60-71.

Urban, Glen L., and Eric von Hippel, "Lead User Analyses for the Development of New Industrial Products," *Management Science* 34, no. 5 (May 1988):569-82.

von Hippel, Eric (1988), *The Sources of Innovation*, New York: Oxford University Press
von Hippel, Eric (2006), *Democratizing Innovation*, Cambridge MA: The MIT Press.

ⁱ Readers wishing further information on the Statistics Canada surveys used in this paper may go to the Statistics Canada website (www.statcan.gc.ca). Then select Definitions, Data Sources and Methods, Surveys and Statistical Programs (by subject) or Questionnaires (by subject), and then select Science and Technology and Innovation.