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

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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.

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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 that 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 user firms developing process innovations 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 good or a service they develop. In contrast, producer-innovators are firms or individuals that benefit from *selling* a good or a service they develop. Lead users are a subset of all users. Their primary distinguishing feature is that they at the leading edge 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. The authors participated in the development of the questions related to respondents' innovation activities used in this survey.

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 (Statistics Canada 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, (f) 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. (It is sometimes argued that intellectual property rights may actually reduce deadweight loss in the longer run. Innovators, it is suggested, 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. In addition, as we will see later, many user-innovators reveal their innovation-related knowledge right away – and without the incentive of intellectual property rights grants. So the actual extent of this possible 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), and/or improve 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 2008b) 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 that met the criteria of having at least $250,000 in revenues, and at least 20 employees. The response rate for manufacturing was 72.5% and 6,478 completed questionnaires were received.

Respondents to the Statistics Canada Survey of Advanced Technology 2007 were asked whether they had adopted any of a list of 39 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 39 AMT categories. Those answering "Yes" to either (a) and/or (b) were candidates for the follow-up to the AT07 Survey conducted by Statistics Canada. As data collection for the follow-up survey overlapped with the data collection for the AT07, the quota sample of 1,750 user innovators was 67.0% of those identfied as user innovators when the final results of the AT07 were available.

Each plant in the quota sample that indicated that it had modified or developed a technology received one of two follow-up questionnaires (Schaan and Uhrbach 2009). Firms that had modified at least one AMT 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 which 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 questionnaires 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 at least one of 39 AMTs they had adopted. 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 in-house 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%
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%

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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q14. The average cost of labor (for the most recently modified or newly-developed technology)	$228,604	$427,863
The median value of cost of labor (for the most recently modified or newly-developed technology)	$20,000	$77,123
Q15. The average cost of machinery (for the most recently modified or newly-developed technology)	$405,564	567,966
median value for cost of machinery	$40,000	75,000
Q16. The elapsed time required to complete the project (for the most recently modified or newly-developed technology)		
	Per cent	
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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q3. How is the modification (development) of technologies funded in your business unit?		
Internally	98.2	98.5
By customers	7.8	16.8
From other funding sources	6.0	10.8
By suppliers	6.0	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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q6. Does your business cooperate with other business units, firms or institutions to modify (develop) technologies?		
Yes	55.5	65.1
No	44.5	34.9
Q7. Who did your business cooperate with for the modification (development) of technologies?		
Suppliers	85.5	81.8
Other business units in firm	57.8	51.2
Consultants	41.6	40.3
Clients	34.5	51.7
Industrial associations	15.6	17.9
Universities	12.7	30.6
Commercial labs	10.6	21.9
Competitors	8.8	12.5
Federal government labs	5.9	13.8
Colleges	5.6	11.4
Provincial labs	2.4	6.2
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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q4. Which budgets are used for technology modification (development)in your business unit?		
Part of the maintenance budget	49.2	29.4
Dedicated budget for each project	48.8	43.7
Part of the R&D budget	30.5	48.6
Other budget	11.4	13.8
Part of the innovation budget	10.2	9.5

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 7, 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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q11. *Does your business unit use any method to protect your process IP?*		
Yes	46.4	60.3
No	53.6	39.7
12. If yes, how do you protect your IP?		
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	0.7	2.0

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?

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q5. *Do you know of other firms that have carried out (developments) similar to yours?*		
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 of, and/or users 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?

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

Responses from innovators that →	*Modify existing technologies*	*Develop new technologies*
Q8. Does your business unit share the technologies that it has modified (developed) with other firms or institutions?		
Yes	17.2	19.0
No	82.8	81.0
Q9. How does your business unit share the technologies it has modified (developed)?		
At no charge	75.8	47.3
In exchange for something of value (i.e., free equipment)	16.2	27.7
For a fee	13.1	40.2
Other method	12.1	16.1
Q10. Why did your business unit choose to share the technologies that it modified (developed)?		
To allow a supplier to build a more suitable final product	53.9	53.6
Gain feedback and expertise	41.2	48.2
Nothing to lose (no direct competition)	36.3	26.8
Enhance reputation	35.3	46.4
Other	15.7	14.3
Contractual obligation	14.7	28.6

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 39 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

As was mentioned earlier, 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 should 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 collaborative problem-solving infrastructure, 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.

6. Suggestions for next steps

Earlier, we pointed out the present paucity of statistical indicators focused upon user innovation and the transfer of user innovations to producers. In this final section we explore this matter and what might be done about it in more detail.

6.1 Changes in the conceptual framework for indicator development

We have seen that the transfer and diffusion of user-developed innovations are important. It is also the case that these important activities are not being well measured today. Chapter 5 of the Oslo Manual (OECD/Eurostat 2005) discusses linkages between firms and other institutions, and provides some guidance for measuring the transfer of innovations among such parties. This is a beginning. The next step is actual development of indicators that can better measure the flow of information from user-innovators, whether this occurs by means of intellectual property licensing or sale or via free revealing. This next step should be a consideration for the next revision of the Oslo Manual.

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 new 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 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.

There are related questions about measuring innovation by public institutions which are attracting attention (OECD 2006). Public institutions can engage in a full range of innovation activities, such as R&D, capital investment, training, and acquisition of knowledge in various forms. However, as in the case of innovations developed by consumers, without connection to the market these activities also do not give rise to innovation as currently defined in the Oslo Manual. This issue should also be addressed.

6.2 New indicators on user innovation and user innovation transfers

With respect to indicator development in the business sector, 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, as was mentioned earlier, the development of indicators and 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 significant evidence now available on all 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 on the Innovation Strategy 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.

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[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.