Measuring user innovation:
What can a standard innovation survey tell us?

Stéphane Lhuillery
stephane.lhuillery@epfl.ch

Marcel Bogers
marcel.bogers@epfl.ch

Ecole Polytechnique Fédérale de Lausanne (EPFL)
Collège du Management de la Technologie
Chaire en Economie et Management de l'Innovation (CEMI)
Odyssea - Station 5
CH – 1015 Lausanne

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Comments are welcome

Abstract:

In this paper, we explore the amount and impact of firms that can be considered being user innovators. Using the Swiss Innovation Survey, we identify a sample of *innovative* firms that we explore with regard to their commitment to R&D. We thereby create a measure for *informal innovation*—that is, innovation not explicitly planned and budgeted—by identifying *innovative* firms that *do not* conduct any R&D. We argue that user innovators are the main source of such technological innovation and propose two methods to measure the usually hidden (informal) activities. First, by defining user innovators as non-R&D innovators, we show that they comprise 46% of all innovating firms. Furthermore, they represent more than one third of the economic impact induced by product and process innovations. A second method defines user innovators as *over-innovators* in an innovation function. Exploring the residuals, we show that user innovators in process technology comprise about 38% of process innovating firms and that they represent 37% of reduced costs in the economy. Furthermore, for these user innovators, 40% of costs reductions are found to be induced by users (within the firms). Thus, about 15% of the overall cost reductions in the economy comes from user innovation within firms.

JEL classification: O31, C34, C35, C81

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1 Introduction

Innovation is widely acknowledged to play an important role in the survival of many firms (e.g., Schumpeter, 1942; Teece, Pisano, and Shuen, 1997), and as a main driver for economic growth (e.g., Aghion and Howitt, 1998). Research on innovation to date investigates the determinants and effects of different kinds of innovation, in particular *technological* innovation for which formalized R&D activities are an important input. However, other determinants of technological innovation have to be investigated as well (e.g., van de Ven, 1986). Non-R&D activities that are acknowledged to play an important role in a firm's innovation efforts and performance are for example marketing, design and engineering capabilities, training and learning (e.g., learning by doing), development new production facilities, and organizational investment and change (Dosi, 1988; Kline and Rosenberg, 1986; OECD, 1997; Rosenberg, 1976). According to Dosi (1988), these informal efforts are embodied in people and organizations (see also Pavitt, 1986; Teece, 1977, 1986), and hard to measure (Rosenberg, 1982: 121-122). It is in these lines that we refer to *informal innovation* as innovation that is not explicitly planned and budgeted and therefore remains largely hidden in (aggregate) innovation data. Informal innovation can therefore be contrasted to formal R&D activities that are traditionally considered as a systematic and organized activity by innovation or R&D surveys (cf. OECD, 1963, 1997, 2002).

One source of informal innovation is learning by doing, which implies 'on-line' improvements deriving from the efforts of employees on the production floor. This could relate to seemingly formal activities, such as engineering, that can actually have significant informal attributes (e.g., King, 1999; Rosenberg, 1982; Vincenti, 1990). An important issue is to systematically measure this source of innovation that is still often ignored (cf. von Hippel, 2005). Still, the informal innovative activities that take place during production could have a significant impact on productivity growth (Dosi, 1988; Rosenberg, 1982). Therefore, and in line with the work of von Hippel (1976; 1982; 1988; 1994; 2005), we investigate user innovation as innovation that takes place within firms as users of (process) technology. "Users [are] firms […] that expect to benefit from *using* a product or a service. […] Users are unique in that they alone benefit *directly* from innovations."[1] (von Hippel, 2005: 3; original emphasis) Despite a strong and growing body of literature on users as innovators, there is still a lack of a systematic measure of user innovation and of its economic impact. Another problem is the methodological difficulty in innovation measurement that derive from the fuzzy boundaries of measured and the variety of sources of innovation. This could give an ambiguous view on innovation, for example by ignoring the informal side of it.

In this paper we first address this issue of informal innovation by pointing out some of the problems and limitations of research on innovation measurement, and by suggesting how 'on-line' improvements (from learning by doing) could explain a large part of these informal innovation efforts and outcomes (Section 2). Furthermore, we empirically explore informal innovation by showing how many and what kinds of firms are involved in it, and what their weight is in the innovation system (Section 3). We do this by using a statistical method to reveal a part of the innovation process that is ordinarily missed and thus ignored. We use the Swiss Innovation Survey and assume that informal innovators are more likely to be found in a particular class of innovating firms that do not invest in any internal R&D activities. We investigate the characteristics of these firms with regard to size and technology intensity and external sources of innovation. We give evidences that non-R&D innovators are 46% of innovating firms, which represent more than one third of the economic impact, induced by product and process innovations. We continue our statistical investigation on user innovation by acknowledging that

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[1] Users can also be individual consumers but this is not in the scope of this paper.

informal innovation can also exist besides internal R&D activities. In this case, the informal inventive activity is considered as an omitted variable in a process innovation production function for which usual observable inputs are taken into consideration. By exploring residuals (Section 4), we show that firms that are more likely to be user innovators can be identified, for example as a selection criterion for case studies. We also show that user innovators (in process technologies) comprise about 38% of all process innovating firms, thereby representing 37% of reduced costs in an economy. Process innovation by users is then estimated to represent 40% of the cost reductions of all user firms (in process technologies). Therefore, we find that around 15% of the overall cost reductions in the economy are induced by user innovators.

2 Measurement of innovation: some frontiers and caveats

2.1 Informal technological innovation as a neglected category of innovation

The measurement of innovative activities rely either on the characterization of the innovative process or practices or try more often to identify inputs and outputs from this process (Godin, 2005; Smith, 2005). On the measurement of the *output* of innovation, important distinctions are usually made to improve the conceptualization and measurement of innovation: process innovation is separated from product innovations, radical innovation from incremental innovation, and more recently technological from non-technological innovation (Lhuillery, 2001; OECD, 1997). However, the distinctions are sometimes fuzzy (see Simonetti, Archibugi, and Evangelista, 1995). The scattered results in innovation studies may raise doubts about the common understanding of the underlying concepts.

Another important historical development is the effort dedicated to measure the in*puts* of innovation. While early attempts to measure innovation mainly relied on formal R&D data (OECD, 1963), there is a more recent attempt to get a better view of the knowledge production factors within a firm enlarging creative works to “knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications”(OECD, 2002: 30) or to informal R&D (Archibugi, Cesaratto, and Sirilli, 1987, 1991; Kleinknecht, 1987, 1989; Kleinknecht, Poot, and Reijnen, 1991; Santarelli and Sterlacchini, 1990).

Although these categories lead to interesting results, there are still some important elements not dealt with. In particular, when non-technological innovation is considered, non-R&D innovation is still poorly addressed in the literature. It is in fact a paradox to see that the Oslo Manual (OECD, 1997) does criticize the usual view of the innovation process where the R&D activities take a central place but subsequently does not consider it in that much more detail. An explanation for this could be that the Oslo Manual has to be articulated in line with the Frascati Manual (OECD, 2002) and thus rather insists on outputs than on inputs at the source of technological invention and innovation. Hence, non-R&D activities are considered here as complementary to R&D activities rather than substitutes.

In contrast, the definition of innovative activities complementary to R&D is extended. In the CIS4 questionnaire, for example, activities that are considered besides the intramural and extramural R&D activities are: the acquisition of machinery, equipment and software, the acquisition of external knowledge, training expenditures, all forms of design costs, marketing expenditures. Here, non-R&D costs are introduced or even extended but are still not exhaustive since items as standardization and normalization costs, or patent costs could be proposed. These activities do not include inventive activities that could be a substitute for the R&D activities that remain at the core of the innovation process. The suggested firm strategy for innovation is therefore: to choose to invest in R&D or not, outside or inside, to buy external knowledge or not, and to choose whether or not to invest in complementary assets that raise the likelihood of success of the innovation. However, there is still no place in this literature for two other inventive activities such as:

- a technological innovation process without any R&D;
- a technological innovation at the level of the individual employee not planned for in R&D.

Table 1: Activities considered in innovation measurement literature

		R&D activities	
		Yes	***No***
Inventive activities without R&D	***Yes***	**Next to or substitute for R&D: Not considered** Complementary to R&D: Yes (Oslo Manual)	**Not considered**
	No	Standard conception (Frascati Manual)	Non-innovative firms

This brings us to the development of a specific framework for the different innovation activities that are considered in the measurement of innovation (Table 1). From Table 1Table 1 it becomes clear that there is little misconception in the bottom part of the table. That is to say, if there are no internal inventive activities *without R&D* while there are (formal) R&D activities (aimed at the development of innovation), firms are assumed to be innovative according to the ordinary definition of the Frascati Manual (OECD, 2002). Furthermore, if the are no (formal) R&D activities and no non-R&D inventive activities, a firm is considered to be non-innovative. However, problems arise in the two top cells of Table 1 where there exist inventive activities *without R&D*. Even if complements to R&D activities are considered by the Oslo Manual (OECD, 1997), the literature ignores technological inventive activities without R&D that take place as a stand-alone activity—that is, next to or as a substitute for R&D—while there are ongoing R&D activities. In addition, inventive activities without R&D in non-R&D firms are ignored as well.

2.2 Characterizing informal innovation: on-line inventions

In order to investigate the two last caveats, mechanisms that underlie informal innovation still need to be explored. The idea that individual capabilities to invent new technological artifacts or introduce technical change can exist without R&D activities, is not unfamiliar to the innovation literature. In particular, a well-known concept is *learning by doing* that takes place for a given production technology (Arrow, 1962). In Arrow's (1962) model, progress is induced by the combination of an exogenous progress—that is, the acquisition of new machines with better performance—with an endogenous learning process that the new machines induce. According to Rosenberg (1982), there is a related form of learning by doing: "The point here is that there are many kinds of productivity improvements, often individually small but cumulatively very large, that can be identified as a result of direct involvement in the production process. This is a source of technological innovation that is usually not explicitly recognized as a component of the R&D process, and receives no direct expenditures—which may be the reason why it is ignored." (Rosenberg, 1982: 121-122) It should be noted that Rosenberg's idea fits our notion of informal innovation and that this is often referred to as *learning by using* in literature.

While there is a large amount of studies that investigate the direct relationship between production (and learning) and productivity growth (Argote, 1999; Dutton and Thomas, 1984; Hayes and Clark, 1986; Yelle, 1979), there is sparse evidence—in line with Rosenberg (1982)—indicating that learning is not always just an 'autonomous' or 'first-order' by-product of 'doing' but it can also be induced or deliberate and managed (Adler and Clark, 1991; Geroski and Mazzucato, 2002; Hatch and Mowery, 1998; Macher and Mowery, 2003; Malerba, 1992; Zollo and Winter, 2002). This implies that the production or shop floor's technological inventions or improvement can be an important contributor to a firm's innovative capacity and related productivity growth and competitiveness.

The contribution of von Hippel (1988; 2005) insists more than Arrow (1962) and Rosenberg (1982) on the ability to produce new knowledge and technological artifacts by using technologies. The process can be seen as a trial-and-error (problem-solving or experimentation) process in which the (solution) knowledge that is generated is combined with the need of the user (Thomke, 1998, 2003; von Hippel, 1994). Von Hippel's (2005) analysis holds important implications that allow us to study a firm's internal users' inventions. This learning by users is often related to the need to interrupt the ongoing activity—by a process of experimentation or problem-solving (von Hippel and Tyre, 1995). In order to get a more precise view, a distinction between 'off-line' and 'on-line' activities is useful (cf. Foray, 2004: 60; Nelson, 2003). *Off-line* largely refers to R&D activities that are isolated (at a distance) from the regular production of goods and services, while *on-line* activities refer to learning during the course of production (cf. Pisano, 1994, 1996, 1997). The process of on-line innovation involves a continuing series of small experiments on the shop floor, designed to produce incremental gains in knowledge (Garvin, 1993)—in other words, on-line experimentation is also at the heart of this innovation process (Foray, 2004). Our notion of informal innovation thus builds on a different concept than R&D but instead relies more on (on-line) learning and capabilities that remain hidden in other activities of the firm (cf. Cooke, 2002; Leonard-Barton, 1988, 1992; Tremblay, 1998).

Below, we try to measure the informal technological innovation that is assimilated to innovation coming from users. Informal innovators is thus to be considered thereafter as a synonym for user innovators. We claim that this category can be approximated by non-R&D innovators or considered as over-innovators in an innovation production function.

3 User innovation as non-R&D innovation

3.1 Innovative firms and their commitment to R&D

In line with the concepts and definitions described in the previous sections, we first focus on innovative firms that introduce product and/or process innovations without conducting any R&D (see Appendix 1). We thereby particularly address the upper right quadrant of Table 1. As already indicated before, an innovative firm can also innovate in processes or products without any declared R&D. We therefore first define an informal innovation or user innovation as a technological innovation that does not require any R&D activities—neither continuous nor discontinuous—within the firm.

Table 2 shows that 57% of Swiss *innovative* firms does not invest in internal R&D activities whereas 20% are involved in continuous R&D. The weight of informal innovators using the sales of innovators is restricted to 46% since informal innovation is more dedicated to SMEs and micro firms (Table 2). It shows that a majority of firms may be ignored when one focuses mainly on R&D activities[2].

Table 2: Innovative firms and their commitment to R&D, by classes of employees

Size	***No R&D***		***Discontinuous R&D***		***Continuous R&D***	
	NW	W	NW	W	NW	W
10 to19	66%	70%	21%	19%	13%	11%
20 to 249	54%	55%	24%	22%	22%	23%
250 and more	40%	36%	14%	7%	46%	57%
Total	57%	46%	23%	14%	20%	40%

NW=Not weighted; W=Weighted; Weighted stands for weighted by 2001 sales

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[2] Only 2% of innovative firms without R&D do patent their innovation whereas this share rises to 36% for continuous R&D firms.

Table 3: Innovative firms and their commitment to R&D, by sectors

Sectors	*Rank*		*No R&D*		*Discontinuous R&D*		*Continuous R&D*	
	NW	W	NW	W	NW	W	NW	W
Transportation/ telecommunication	1	17	76%	32%	18%	5%	6%	63%
Retail	2	1	74%	85%	25%	9%	1%	6%
Building	3	4	72%	72%	14%	14%	14%	14%
Printing & Publishing	4	6	70%	65%	25%	29%	5%	6%
Banking/ insurance	5	13	70%	45%	11%	16%	19%	39%
Automotive	6	5	66%	71%	9%	7%	25%	22%
Wood	7	14	63%	44%	30%	43%	7%	13%
Paper	8	11	63%	51%	22%	10%	15%	39%
Energy	9	3	61%	79%	23%	15%	16%	6%
Metal products	10	12	59%	48%	22%	26%	19%	26%
Hotel and restaurant industry	11	9	59%	54%	38%	44%	3%	1%
Information technology services/ R&D	12	7	59%	59%	8%	11%	33%	30%
Services for enterprises	13	2	59%	80%	24%	9%	17%	11%
Food	14	22	53%	19%	35%	20%	12%	61%
Textile	15	10	52%	52%	22%	17%	26%	31%
Non-metallic minerals	16	8	49%	54%	31%	22%	20%	24%
Clothing	17	15	47%	38%	26%	28%	27%	34%
Other manufacturing	18	16	46%	38%	27%	32%	27%	30%
Electronics/ instruments	19	18	45%	30%	8%	3%	47%	67%
Electrical equipment	20	20	41%	20%	19%	7%	40%	73%
Machinery	21	23	40%	16%	17%	7%	43%	77%
Clock making	22	21	38%	20%	27%	8%	35%	72%
Rubber & Plastics	23	19	33%	28%	38%	35%	29%	37%
Chemicals	24	24	10%	0%	20%	3%	70%	97%
All			57%	46%	23%	14%	20%	40%

NW=Not weighted; W=Weighted; Weighted stands for weighted by 2001 sales

Table 3 shows that innovative firms belonging to the service sectors are more inclined to be informal innovators than manufacturing firms. High-tech industries moreover tend to formalize their production of knowledge through an R&D activity and are therefore less inclined to innovate informally. As shown in Table 3, R&D data in several service sectors hide more than two third of the innovative firms whereas very few are missing in a sector as the chemical industry. Pavitt's (1984) typology gives a more precise partition: scale intensive firms, which tend to develop their process technology themselves in-house, such as metal manufacturing, paper, automotive and food (although not if weighted by sales), are relatively highly ranked as informal innovators. While the same can be said about some supplier-dominated firms such as building and financial and commercial services, the converse is true (as also expected) for specialized suppliers as machinery and instruments as well as for science-based firms as electronics and (as already mentioned) chemicals. The results are furthermore largely in line with some of the expectations deriving from a taxonomy of innovation small firms (de Jong and Marsili, 2006).

Table 4: Types of output by type of input for innovative firms

	No R&D		*Discontinuous R&D*		*Continuous R&D*		*Total*	
	NW	W	NW	W	NW	W	NW	W
Process	67%	76%	74%	85%	84%	72%	69%	80%
Product	83%	75%	94%	85%	97%	98%	87%	85%
Both	50%	51%	68%	70%	81%	70%	58%	65%
Product Innovation only	33%	24%	26%	15%	16%	28%	29%	20%
Process Innovation only	17%	25%	6%	15%	3%	2%	11%	15%

NW=Not weighted; W=Weighted; Weighted stands for weighted by 2001 sales

Informal innovation can be divided into two different kinds of technological innovation. 67% of firms without R&D implement *process* innovation, and 83% *product* innovation (Table 4). Half of informal innovators are both process and product innovators, while one third is involved in product innovation only. Thus, non-R&D innovation is associated with both product innovation and process innovation. The share of firms innovating only at the process level increases with decreasing R&D activity. If weighted by their sales, it appears that process innovators reach the level of product innovators (Table 4). Hence, even if fewer non-R&D firms are involved in process than product innovation, they are larger (by sales).

The results are in line with the results of Kleinknecht and others (Kleinknecht, 1987; Kleinknecht and Reijnen, 1991; Santarelli and Sterlacchini, 1990) on informal R&D because there is a similar effect of size and sectors. Nevertheless, it goes beyond the concept of informal R&D by showing that non-R&D innovative activities are ignored and represent a large part of technological innovation in the economy.

3.2 The economic impact of informal innovation

The (relative) weight of informal innovative firms does not tell us what the weight of informal innovation in an economy is. A further step therefore is to weigh the firms by the outcome of their technological innovative process. This shows the impact of informal innovation on the level of the economy.

Table 5: Process and product innovation impact, by classes of employees

	Process				Product			
Size	No R&D	Discontinuous R&D	Continuous R&D	Total	No R&D	Discontinuous R&D	Continuous R&D	Total
10-19	2%	1%	1%	4%	3%	1%	1%	4%
20 to 249	26%	7%	15%	48%	22%	10%	16%	48%
250 and more	7%	3%	38%	48%	15%	1%	31%	48%
Total	35%	11%	54%	100%	40%	12%	48%	100%

All values are weighted by 2001 innovative sales for products and by 2001 cost reduction for process innovation

As far as process innovation is concerned, non-R&D firms account for more than one third of the total reduction of production costs due to process innovation—i.e., the measure for the impact of (informal) process innovation—while continuous R&D firms represent more that half of the progress here (see Table 5). Large firms innovating without R&D do not represent an important part of the progress with only 7% of the whole economized resources. The same remark applies to micro firms, whereas SMEs gather more than a quarter of the whole economic progress due to process innovation. Table 6 furthermore shows that costs are especially reduced by non-R&D activities in service industries. The size of sectors is however important since automotive industries, information industries and wholesale represent near to 15% of the whole progress due to informal process innovation (see Table 6).

Table 6: Process and product innovation impact, by sectors

Type of innovation	*Process*				*Product*			
	Industry weight	*Share of economized costs Between types of firms*			*Industry weight*	*Share of innovative turnover between types of firms*		
Sectors	*No R&D*	*No R&D*	*Discontinuous R&D*	*Continuous R&D*	*No R&D*	*No R&D*	*Discontinuous R&D*	*Continuous R&D*
Clothing	**0.0%**	**0%**	100%	0%	**0.5%**	**27%**	14%	59%
Chemicals	**0.1%**	**1%**	1%	98%	**0.0%**	**0%**	2%	98%
Clock making	**0.1%**	**2%**	2%	96%	**0.7%**	**19%**	10%	71%
Transportation/ telecommunication	**1.4%**	**9%**	1%	90%	**0.8%**	**15%**	4%	81%
Machinery	**0.6%**	**17%**	11%	71%	**0.4%**	**9%**	7%	84%
Electronics/ instruments	**2.0%**	**24%**	3%	73%	**0.7%**	**15%**	2%	83%
Rubber & Plastics	**0.7%**	**26%**	45%	29%	**0.2%**	**8%**	42%	50%
Electrical equipment	**1.0%**	**27%**	16%	57%	**0.8%**	**19%**	9%	72%
Textile	**0.9%**	**30%**	5%	65%	**0.9%**	**34%**	14%	52%
Food	**0.4%**	**31%**	19%	50%	**0.5%**	**17%**	19%	64%
Wholesale	**4.5%**	**39%**	9%	52%	**6.4%**	**59%**	20%	21%
Wood	**1.6%**	**46%**	54%	0%	**0.6%**	**33%**	21%	46%
Metal products	**1.7%**	**48%**	22%	30%	**0.6%**	**37%**	40%	23%
Other manufacturing	**0.6%**	**50%**	8%	42%	**0.9%**	**39%**	47%	14%
Paper	**1.3%**	**53%**	38%	9%	**0.7%**	**21%**	4%	75%
Banking/ insurance	**1.7%**	**58%**	27%	15%	**5.0%**	**33%**	1%	66%
Non-metallic minerals	**1.6%**	**58%**	20%	22%	**0.6%**	**39%**	15%	46%
Information technology services/ R&D	**5.2%**	**61%**	10%	29%	**7.3%**	**78%**	5%	17%
Building	**0.2%**	**65%**	35%	0%	**0.1%**	**47%**	43%	10%
Hotel and restaurant industry	**0.3%**	**77%**	23%	0%	**1.1%**	**37%**	63%	0%
Printing & Publishing	**1.5%**	**77%**	19%	4%	**0.4%**	**35%**	52%	13%
Services for enterprises	**1.2%**	**85%**	12%	3%	**1.4%**	**66%**	12%	22%
Automotive	**5.2%**	**87%**	0%	13%	**6.5%**	**78%**	4%	18%
Retail	**1.0%**	**100%**	0%	0%	**2.6%**	**74%**	19%	7%
Total	**35%**	**35%**	11%	54%	**40%**	**40%**	12%	48%

The same procedure applies to product innovation. However, instead of the contribution to cost reduction the weight is given by the turnover made by product innovation—i.e., the measure of the impact of (informal) product innovation. 40% of innovative sales are not considered if only R&D firms are considered (Table 5). This loss is higher with decreasing firm size. As it is the case for process innovation, within the group of informal innovators, SMEs capture the main amount of innovative sales. Combined with micro firms, 25% of the economic value of product innovation is produced by non-R&D innovators (Table 6). By sectors, the weight of non-R&D product innovation is also undermined in service industries such as bank and insurance (see Table 6). It could be noted that the interpretation of some sectors should be done cautiously because of their small size. This latter sector (bank and insurance) is namely relatively large in Switzerland and it is therefore overestimated compared to other countries (dividing this figure by two would give a good indication for other countries.)

3.3 Are non-R&D innovators dominated by suppliers?

As we claim that informal innovation is largely about user innovation, we acknowledge (and control for) other aspects that can influence the production of knowledge for innovative firms. For example, external sources of innovation (e.g., equipments, R&D cooperation or subcontractors, externalities) and internal organizational practices (e.g., team working) can influence the likelihood to be a non-R&D innovator. In particular, a firm can rely on the acquisition of new machines to improve its production process or to improve its product quality. In this case, a measurement problem is that firms may declare to be innovative while they are not. The probability to get non-R&D innovators may be higher for firms that are supplier dominated from a technological point of view. Due to our definition of informal (user) innovation, we can do little about the error of rejecting user innovators that are investing in R&D (as we only capture the informal, non-R&D innovators). However, this only creates a conservative measure of user innovation. On the other hand, we can mitigate the error of the second kind of not rejecting firms that are not user innovators (because their informal innovation is coming from other sources). In order to check for the robustness of our assumption on the prevalence of user innovators among non-R&D innovators, we explore the characteristics of firms investing in discontinuous or continuous R&D compared to firms that do not conduct any R&D. Appendix 2 presents the details of the econometric regressions that we did. R&D investments are influenced by several internal and external variables. Beside control variables such as industry and size, external sources of innovation can be considered as substitutes for or complement to R&D activities.

If our distinction between R&D innovators and non-R&D innovators (as user innovators) holds—that is, the possible bias induced by supplier dominated innovative firms is negligible—coefficients of 'external technological knowledge suppliers' should be not significantly different from 0, explaining nothing in the decision to invest in R&D or not. The same expectation concerns the coefficients of R&D cooperation with these suppliers. Our results show that R&D firms are not less influenced by suppliers than other innovative firms. The results are confirmed by a Wald test (see Appendix 2). These results legitimate our categorization of R&D and non-R&D innovators.

4 User innovation as a residual innovation

4.1 User innovators as an omitted variable in an innovation function

An obvious and critical problem in the previous section is that user innovators are assumed to be restricted to non-R&D firms and therefore to be found in this class of firms more frequently. This assumption supposes implicitly substitutability between user innovation and R&D activities and that the amount of reduced costs due to user innovators among R&D firms is slight. We now propose to relax this assumption and to explore user innovation in all kinds of firms. Let us suppose that user innovators are omitted in typical innovation functions, although they belong to the true model of innovation. Innovation is a function of a set of factors such as internal factors (R&D, organization), external determinants (externalities, cooperation), and other heterogeneity aspects to control for (industry, size). In usual econometric investigations, we thus have the model G: $INNO = G(Internal, External, Control)$ instead of the real model F: $INNO = F(Internal, External, USER, Control)$.

The exclusion of a relevant variable such as USER, gives several problems for econometric investigations that try to identify the true effects of all determinants of innovation, for either products or processes. A direct consequence is that the different parameters in the underspecified model may be biased. That is, if knowledge is assumed to be produced by only two factors (R&D and user innovation), the effect on R&D is biased and the sign of the biases relies on the covariate between the observable variable (R&D costs) and user innovation costs. If R&D and user innovation produce substitute knowledge, the R&D coefficient will be downwardly biased. Conversely, if user innovators (employees working ‘on-line’ as users of process technology) are complementary to R&D employees, the R&D coefficient would be upwardly biased. Other determinants may also be influenced by the omission of user innovators (see Wooldridge, 2002). This first aspect is often neglected in studies exploring the impact of R&D on productivity, for example. We now turn to the measurement issue of the residual considered as a new measure of user innovation.

4.2 User innovators as over-innovators

Since we can only identify the innovation function G, user innovators are included in the error terms. We assume that the empirical model G has a residual ε. According to the idea that the missing variable is USER, we further assume that $\varepsilon_i = \delta USER_i + v_i$. The residuals of the innovation function are thus likely to be correlated with user innovators’ activities. A positive impact of user innovators on innovation performances is expected. Positive residuals are therefore a proxy for user innovation since firms with such residuals are over-innovators relatively to their characteristics. We therefore define user innovators as technological innovators that over-perform other innovative firms with the same innovation inputs and characteristics.

However, this idea to use positive residuals as a measure for user innovation has a shortcoming since an important fraction of firms declares a zero output from their innovation either for process innovations (cost reduction is 0) or product innovation (innovative turnover is 0). This result may come from many aspects. First, cost reduction can be declared at 0 when firms consider that the process innovation did not reach a significant threshold. Second, process innovation could have been introduced too recently in the 1999-2001 period to give observable improvements in 2001. Third, the innovation may introduce a production with better quality that is hard to quantify (e.g., less tiring for workers). Similar arguments can be put forward for product innovation.

As a consequence, it is hazardous to use here a linear model. Such a specification can lead to negatively fitted values when innovative turnover and cost reduction belong to the [0;1] interval. When a Tobit model is investigated, the computation of simple residuals ε_i is straightforward but misleading when observed values are at 0. Chesher and Irish (1987) propose a method to compute generalized residuals ε_i^* taking into account the censoring aspect. The generalized residuals can be computed as $\varepsilon_i^* = d_i \frac{y_i - \alpha x_i}{\sigma} - (1-d_i)\frac{\phi_i\left(-\alpha x_i / \sigma\right)}{\left[1-\Phi_i\left(-\alpha x_i / \sigma\right)\right]}$, (see Cameron and Trivedi, 2005; Greene, 2005) where $d_i = 1$ if $REDUCOST_i > 0$, 0 otherwise. The usual residual ε_i is thus corrected by a second term and is a particular case when all the explained variables can be observed in the sample (d=1 only).

In this paper, as we are interested in user and thus process innovation, we only present results on the process innovation side, while we neglect the correlation between process and product innovations. The product innovation function is indeed much harder to control since marketing aspects enter into consideration (advertisement, marketing strategies and organization) and because the influence of customers is already taken into account in the external sources of knowledge. A risk is therefore to capture another major omitted variable (i.e., marketing) in the product innovation function as well as another form of innovation that may be partly taken into account (user innovation coming from active clients). The estimation results are reported in Appendix 3 since they are not directly useful for our purpose in this paper.

4.3 Identifying and characterizing user process innovators

If user innovators are acknowledged to belong to firms with positive residuals in an innovation function, three different results can be put forward. First, sorting the 934 process innovators on their residuals allows us to identify the main over-innovators that are considered to be firms for which the influence of user innovators is high. Conversely to the previous section, user innovators with R&D can also be identified. Table 7 is a list of top 20 user innovators. The econometric results can lead academics to interview these firms in order to give a better (qualitative) understanding of these user innovators. More generally, positive residuals can be used as a population for a sampling of cases. The method of case selection is thus original compared to usual random sampling or theoretical sampling (Eisenhardt, 1989; Yin, 2003). As Table 7 suggests, the identified firms are scattered among different industries and are not clustered around a specific activity.

Table 7: Identification and characteristics of user innovators as residual innovators

Id	Residuals	Industry (Nace – 2 digits)	Number of employees	R&D	Continuous R&D
Firm1	3.36	Manufacture of machinery and equipment	65	Yes	No
Firm2	3.21	Medical, precision and optical instruments, watches	95	Yes	No
Firm3	2.51	Land transport, transport via pipeline	50	Yes	Yes
Firm4	2.45	Fabricated metal products	70	Yes	No
Firm5	2.33	Radio, television and communication equipment	46	Yes	No
Firm6	2.24	Other business activities	210	No	No
Firm7	2.22	Recycling	45	Yes	Yes
Firm8	2.21	Manufacture of machinery and equipment	36	Yes	Yes
Firm9	2.19	Manufacture of machinery and equipment	238	Yes	Yes
Firm10	2.11	Publishing, printing and reproduction of recorded media	50	No	No
Firm11	2.11	Activities auxiliary to financial intermediation	14	Yes	No
Firm12	2.11	Manufacture of food products and beverage	40	No	No
Firm13	1.91	Retail trade, except motor vehicles and motorcycles	68	No	No
Firm14	1.87	Wholesale trade and commission trade	15	No	No
Firm15	1.87	Manufacture of rubber and plastic products	101	No	No
Firm16	1.83	Activities auxiliary to financial intermediation	391	Yes	Yes
Firm17	1.79	Manufacture of machinery and equipment	198	Yes	No
Firm18	1.77	Supporting and auxiliary transport activities	10	Yes	No
Firm19	1.72	Other business activities	33	Yes	Yes
Firm20	1.71	Manufacture of food products and beverage	102	Yes	No

A second outcome is that the repartition of the positive residuals helps us to estimate the frequency and economic weight of user innovation firms. As reported in Table 8, we find that user innovators comprise 38% of all process innovating firms, which represent about 37% of reduced costs in the economy. The magnitude is similar to the results obtained by focusing only on non-R&D innovators (see Section 3). However, firms without R&D represent 55% of user process innovators and about 14% of cost reductions in the economy, which can be explained by their size. (45% of the user innovators thus perform some sort of R&D.) In contrast, user innovators that also perform continuous R&D (8% of the total sample and 20% of all user innovators) have the largest economic impact (71%) of all user innovators. We can also see that for all categories of firms—both for number of firms and cost reductions—user innovators comprise around 40% of the economy.

Table 8: Frequency and weight of user innovators

		Number of firms				Reduced costs			
		No R&D	Discontinuous R&D	Continuous R&D	All	No R&D	Discontinuous R&D	Continuous R&D	All
Total %	With user innovations	21%	9%	8%	38%	5%	6%	26%	37%
	Without user innovations	38%	13%	12%	62%	7%	8%	48%	63%
	All	58%	23%	19%	100%	12%	14%	74%	100%
Row %	With user innovations	55%	25%	20%	100%	14%	15%	71%	100%
	Without user innovations	60%	21%	19%	100%	11%	13%	76%	100%
	All	58%	23%	19%	100%	12%	14%	74%	100%
Column %	With user innovations	35%	41%	39%	38%	43%	40%	36%	37%
	Without user innovations	65%	59%	61%	62%	57%	60%	64%	63%
	All	100%	100%	100%	100%	100%	100%	100%	100%

A main caveat here is, of course, that we only identify the weight of user innovating firms but not the share and impact of innovation due to users within those firms. A third step is therefore to distinguish, among user innovator firms, the share of reduced costs imputable to user innovations from the share induced by other determinants. In order to deal with this, we use the predicted values coming from the Tobit regression compared to the declared values on cost reductions due to process innovations when declared cost reductions and residuals are positive.

Table 9: Repartition of reduced costs by origin of innovation for user innovators

R&D	No	Discontinuous	Continuous	All
Sources	R&D	R&D	R&D	
From users	48%	50%	37%	40%
From other sources	52%	50%	63%	60%
All	100%	100%	100%	100%

Among the 38% of innovative firms considered as user innovators, Table 9 suggests that about 40% of reduced costs come from users. The share is higher for non-R&D firms or firms investing in a discontinuous R&D activity. Table 9 thus also suggests that process innovations induced by users represents about 15% (37% x 40%) in the Swiss progress due to process improvements. The amount is not that important but has to be cumulated with the product innovations induced by employees and clients (von Hippel, 2005) to give an overall estimation of the importance of user innovations in a dynamic economy. Furthermore, the social rate of return of such user innovations is still ignored (cf. Harhoff, Henkel, and von Hippel, 2003).

5 Conclusion

In this paper, we argued that, although innovation is considered to be a main driver for firm performance and economic growth, there are still important parts of its process that are unknown because of the inherent difficulties to measure it. While some of these limitations are taken away after the work on informal R&D (e.g., Kleinknecht, 1987) there is still an important gap in the literature with regard to non-R&D innovations. While a part of these non-R&D activities are considered as complementary to R&D activities (OECD, 1997), we argue that they can also take place next to or as a substitute for R&D-based innovation. Moreover, we contend that (technological) innovative activities without R&D that take place within non-R&D firms are almost completely ignored.

The present paper shows that user innovation is an important part of the innovation process. Even if we encounter difficulties to identify directly user innovators, we advocate that usual innovation surveys—namely the Swiss innovation survey in our case—can help us to quantify the hidden process. We first assume that user innovators are non-R&D innovators, suggesting that it involves 46% of innovating firms, representing more that one third of innovative outputs. A further investigation encompasses all types of innovative firms assuming that user innovations are characterized with positive residuals in an econometric innovation function explaining cost reductions induced by process innovations. 37% of process innovators are concerned with user sources of innovation. Among these firms, 40% of reduced costs are imputed to users, the remainder relying on usual determinants of innovation. Finally, we estimate that 15% of the gain from process innovation is due to user innovations. The impact of users on product innovations is still to be measured.

From a science and technology (S&T) policy perspective, our results are at odds with the usual tools (grants, R&D tax credit) which are oriented towards R&D and R&D cooperation activities. Neglecting firms that can be considered user innovators could harm a large number of non-R&D innovative firms and may distort the inventive process towards formal knowledge activities (involving R&D). These latter activities can be important with regard to the novelty of an invention but when it comes to market or customer factors, they might not tell the full story. In addition, firms that rely on incremental on-line process innovation for their competitiveness—and these might be many—could be at odds with that focus.

For academics or practitioners working on S&T indicators, it is needless to say that the user innovation topic deserves a further empirical investigation in dedicated questionnaires in order to give the order of magnitude concerning firms and their weight in the innovative system. Several options are available for future research. A first solution to develop the measurement of user innovation is the implementation of an input and output measure in a standard innovation questionnaire.

A second measurement strategy is to develop a specific questionnaire focused on users in the innovation process. To our knowledge, this type of questionnaire is not yet implemented. Three directions could be addressed here: a first issue is to identify user innovators, identifying the location of the different sources (clients, employees). A second question would be to quantify the importance of innovation due to users. The use of the ‘willingness to pay’ literature would be interesting here even if difficulties do exists (von Hippel, 2005). Third, there will be a lot of value in exploring the practices within firms that are (directly) related to the process of on-line innovation. For example, the appropriation practices implemented at the firm level may differ between on-line and off-line innovation. The potential leakage of knowledge could be dealt with by long-life careers, retaining the best on-line innovators within the firm. This last practice leads us to a broader view on human resources management practices, used for both R&D and non-R&D employees (Ichniowski, Shaw, and Prennushi, 1997). Despite heterogeneous motives for inventors (see Cohen and Sauermann, 2006; see Lakhani and von Hippel, 2003; Stern, 2004), a reward structure can be especially designed for on-line inventions in order to stimulate knowledge creation and problem-solving capacity by productive workers, or even to encourage the diffusion of on-line innovations.

6 References

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Appendix I: Data and assumptions

The core data set used in this paper is the Swiss Innovation Survey of 2002, conducted by the Konjunkturforschungsstelle (KOF) or Swiss Institute for Business Cycle Research at the Eidgenössische Technische Hochschule Zürich (ETHZ) in order to investigate the Swiss firms' capability to innovate for more information on the Swiss Innovation Survey and its data and statistical background. The Swiss survey — see Arvanitis and Hollenstein (2004) for further details — is to a large extent adapted to the 'European' Community Innovation Survey (CIS) and the Oslo Manual (OECD, 1997). The survey is based on a (with respect to firm size disproportionately stratified) random sample of 6600 firms with more than 9 employees covering 26 potential industries at the NACE two digits level (energy, real estate and leasing, entertainment, waste disposal, and health care are not considered here because of the restricted size of the sector).

The survey asks for several issues that are related to a firm's organization, market and activities, and its innovations. The questions relate to the general characteristics of the firm and its market, its innovation activities (focusing on both product and process innovation), (national and foreign) R&D activities, innovation expenditures, public support for innovation, R&D collaborations, protection of innovation related competitive advantage, technological potential, external sources of information for innovation, strategic and organizational changes, and constraints for innovation.

The questions in the questionnaire on R&D make the distinction between continuous and discontinuous R&D, in addition to *no* R&D. The trade-off between continuous and discontinuous R&D is central to the literature on informal R&D (e.g., Kleinknecht, 1987, 1989; Kleinknecht and Reijnen, 1991). Innovative firms that introduce product and/or process innovations which are defined as being significantly changed or new (to the firm) technologies. In the Swiss questionnaire, it is not possible to identify innovation coming from non technological activities (marketing, design, packaging, etc.). However, the output side of innovation is investigated by asking for the usual impact of the innovations in terms of innovative sales for product innovation. More original is the Swiss inquiry in the cost reduction induced by process innovations.

Our final sample includes 1275 innovative firms. There are some sectors without many respondents (automotive industry and clothing) that we nonetheless keep in the sample at the two digit level because of the difficulty to aggregate them with others.

Appendix II: Explaining R&D forms

The decision to invest in R&D is influenced by several internal and external variables besides control variables such as industry and size. External sources of innovation can be considered as substitutes for or complements to R&D activities. However, the substitutability hypothesis is rather supported when R&D intensity and suppliers are considered (see Cohen and Levinthal, 1990). More simply, in order to investigate the external influences on the non-R&D innovators, we explain the probability to invest or not in R&D. Our empirical model is an ordered logit. The main estimated equation orders the three R&D choices according to the R&D regularity to build the trichotomic RDFORM variable (No R&D=1, Discontinuous R&D=2 and continuous R&D=3) that is supposed to be correlated with R&D intensity as well. The left hand side variable is regressed against a set of firm characteristics: external sources of technological knowledge (EXT SOURCES are 1 when the source is declared important or very important on a 5 point Likert scale), R&D partners (COOP is 1 when a type of firm is declared to be a partner), and legal appropriability of innovations (APPRO=1 if legal appropriation is declared very efficient on a 5 point Likert scale), the belonging to a group (GROUP=1), size (SIZE), and a set of industry dummies (IND). Our empirical model is a standard ordered logit model as:

$$
\begin{aligned}
P(RDFORM_i = j) \ &= \mathrm{P}(k_{j-1} < \sum_{k=1}^{14} \alpha_k EXT\ SOURCES_{ik} + \sum_{l=15}^{24} \alpha_l R\&D\ COOP_{il} \\
&\qquad \alpha_{25} APPRO_i + \alpha_{26} GROUP_i + \alpha_{27} SIZE_i + \sum_{s=28}^{48} \alpha_s\ IND_{is} + u_i \leq k_j) \\
j &= 1,2,3
\end{aligned}
$$

Where k_j are the cut-off point to be estimated and j is the number of possible outcomes (3 here) (see Wooldridge, 2002). The different external sources or R&D partners are listed in Table 10.

If R&D cooperation can be an important source of knowledge (see Veugelers and Cassiman, 2005), the knowledge jointly produced should be taken into account through the EXT SOURCES variables. Another argument is that R&D collaborations usually concern only R&D firms. This introduction into our specification could also lead to multicollinearity problems. However, the introduction of the different sources one by one does not lead to different results. Furthermore, blocks of external factors are introduced successively (see Table 10). Finally, a Wald test is implemented to test multiple null hypotheses for potential correlated suppliers.

In order to align with the classification introduced in section 3, we do not pay attention to the differences between product and process innovation. To deal with possible differences, we provide results for all innovative firms, for product innovative and process innovative firms.

Table 10: *Ordered logit model explaining R&D forms*

	All innovators		Product only		Process only	
Variable	Spec1	Spec2	Spec1	Spec2	Spec1	Spec2
Sourcing : Clients or customers	0.492*	0.515*	0.547*	0.584*	0.337	0.339
	(0.219)	(0.226)	(0.233)	(0.241)	(0.252)	(0.263)
Sourcing : Suppliers of materials, components	-0.051	-0.063	-0.123	-0.162	-0.185	-0.157
	(0.227)	(0.229)	(0.233)	(0.237)	(0.283)	(0.293)
Sourcing : Suppliers of software	-0.384	-0.322	-0.415	-0.296	-0.384	-0.248
	(0.280)	(0.271)	(0.298)	(0.289)	(0.324)	(0.308)
Sourcing : Suppliers of equipment	-0.211	-0.242	-0.177	-0.195	-0.146	-0.242
	(0.258)	(0.272)	(0.270)	(0.283)	(0.310)	(0.318)
Sourcing : Competitors and other enterprises from the same industry	-0.099	-0.182	-0.35	-0.377	0.041	-0.032
	(0.223)	(0.232)	(0.227)	(0.237)	(0.266)	(0.275)
Sourcing : Firms from the same group	0.428	0.28	0.524	0.356	0.527	0.327
	(0.293)	(0.309)	(0.302)	(0.320)	(0.343)	(0.376)
Sourcing : University and Higher education	0.845*	0.786*	1.012**	0.924*	0.486	0.331
	(0.331)	(0.356)	(0.335)	(0.370)	(0.424)	(0.476)
Sourcing : Other government or semi-private research institutes	-0.072	-0.221	0.229	0.027	-0.19	-0.26
	(0.396)	(0.374)	(0.390)	(0.372)	(0.528)	(0.506)
Sourcing : Consulting firms	0.158	-0.157	0.219	0.012	0.014	-0.454
	(0.380)	(0.357)	(0.412)	(0.394)	(0.442)	(0.425)
Sourcing : Technology Exchange	-0.233	-0.062	-0.341	-0.176	-0.263	-0.15
	(0.414)	(0.393)	(0.433)	(0.414)	(0.489)	(0.444)
Sourcing : Patent reports	0.279	0.126	0.3	0.153	0.298	0.128
	(0.385)	(0.410)	(0.390)	(0.422)	(0.476)	(0.491)
Sourcing : Fairs, exhibitions	-0.204	-0.038	-0.166	-0.033	-0.066	0.133
	(0.250)	(0.258)	(0.261)	(0.269)	(0.295)	(0.307)
Sourcing : Professional conferences, meetings, journals	0.267	0.118	0.127	0.039	0.342	0.189
	(0.235)	(0.246)	(0.246)	(0.259)	(0.282)	(0.295)
Sourcing : Electronic Information networks	0.499	0.474	0.614*	0.497	0.735*	0.769*
	(0.261)	(0.267)	(0.273)	(0.280)	(0.305)	(0.314)
Cooperation: Clients or customers		0.800		0.884		0.277
		(0.497)		(0.503)		(0.624)
Cooperation: Suppliers of materials, components		-0.129		-0.162		0.068
		(0.424)		(0.427)		(0.518)
Cooperation: Suppliers of equipment		-0.669		-0.839		-0.556
		(0.485)		(0.483)		(0.522)
Cooperation: Competitors and other enterprises from the same industry		0.428		0.339		0.681
		(0.393)		(0.395)		(0.500)
Cooperation: Other firms (designers , IT firms)		0.925*		1.030*		0.69
		(0.392)		(0.406)		(0.429)
Cooperation: Firms from the same group		1.453***		1.309**		1.752***
		(0.439)		(0.440)		(0.514)
Cooperation: Universities or other higher education institutes		0.272		0.077		0.158
		(0.537)		(0.564)		(0.594)
Cooperation: Other government or semi-private research institutes		-0.234		-0.233		-0.131
		(0.590)		(0.612)		(0.620)
Enterprise Group	-0.003	-0.262	0.178	-0.132	-0.117	-0.483
	(0.332)	(0.333)	(0.321)	(0.326)	(0.431)	(0.428)
Public support for innovation project	1.337**	1.129**	1.084*	0.929*	1.782***	1.670**
	(0.417)	(0.407)	(0.438)	(0.416)	(0.502)	(0.521)
Size	0.338***	0.362***	0.363***	0.400***	0.348***	0.388***
	(0.089)	(0.087)	(0.095)	(0.095)	(0.106)	(0.101)
Log pseudolikelihood	-1005.9	-961.5	-902.5	-868.2	-716.3	-680.6
Pseudo R^2	0.18	0.21	0.19	0.22	0.19	0.23
H0: All coeff =0	278.4***	317.1***	270.4***	293.5***	197.1***	228.2***
H0: R&D cooperations does influence RD?		54.14***		38.95***		44.46***
H0: Does R&D cooperations with suppliers influence RD?		2.23		3.56		1.13
H0: Does external sources of tech knowledge influence RD?	35.6***	24.17**	41.66***	27.77**	26.56**	19.61
H0: Does suppliers as external sources of tech knowledge influence RD?	4.1	3.52	4.07	3.23	3.47	2.81
Number of obs	1275	1275	1109	1109	934	934

Legend:* p<.10; ** p<.05;*** p<.01 Explained variable: R&DFORM

Robust standard errors in parentheses Cut-off points are not reported.

Appendix III: User innovators as residual innovators

Let us consider an innovation production function where endogeneity of R&D variables is not considered. A simple econometric model explains the cost reduction induced by process innovations (REDUCOST) where reducost is observed only when a process innovation is declared and a lot of observations are 0. We introduce here the same explanatory variables as in Appendix 2, expanded with intensity and structure of innovation costs (see Table 11 for a definition). Our Tobit model is thus:

$$
\begin{aligned}
REDUCOST_i = {} & \alpha_0 + \alpha_1 ICOST\ INT_i \ + \alpha_2 IR\&D_i^{CONT} + \alpha_3 R\&D_i^{CONT} \\
& \alpha_4 ER\&D_i \ + \alpha_5 CCC_i \ + \alpha_6 CIND_i \\
& \sum_{k=7}^{20} \alpha_k EXT\ SOURCES_{ik} + \sum_{l=21}^{27} \alpha_l R\&D\ COOP_{il} + \\
& \alpha_{28} APPRO_i + \alpha_{29} GROUP_i + \\
& \alpha_{30} SIZE_i + \alpha_{31} SIZE_i^2 + \sum_{s=32}^{52} \alpha_s \ IND_{is} + \varepsilon_i
\end{aligned}
$$

where user innovation is extensively repeated as a non-observable variable whereas other traditional determinants (internal and external) and control variables are introduced in the specification.

In this case, user innovators are included in the error term. Thus we assume that $\varepsilon_i = \delta USER_i + v_i$. Even though we do not succeed to properly identify the β coefficients in particular, we *are* interested in residuals. At the same time, possible multicollinearity between external sources and types of cooperation is not of interest anymore.

Table 11: Tobit regression: Explaining cost reduction due to process innovation

	Coeff	S.E.
Sourcing : Clients or customers	0.005	(0.011)
Sourcing : Suppliers of materials, components	-0.007	(0.011)
Sourcing : Suppliers of software	0.011	(0.013)
Sourcing : Suppliers of equipment	0.010	(0.013)
Sourcing : Competitors and other enterprises from the same industry	-0.020*	(0.011)
Sourcing : Firms from the same group	0.011	(0.014)
Sourcing : University and Higher education	-0.019	(0.016)
Sourcing : Other government or semi-private research institutes	0.011	(0.019)
Sourcing : Consulting firms	-0.038**	(0.018)
Sourcing : Technology Exchange	-0.012	(0.022)
Sourcing : Patent reports	0.020	(0.018)
Sourcing : Fairs, exhibitions	0.013	(0.012)
Sourcing : Professional conferences, meetings, journals	0.007	(0.012)
Sourcing : Electronic Information networks	-0.014	(0.014)
Cooperation: Clients or customers	0.014	(0.024)
Cooperation: Suppliers of materials, components	0.002	(0.023)
Cooperation: Suppliers of equipment	0.035	(0.023)
Cooperation: Competitors and other enterprises from the same industry	-0.020	(0.022)
Cooperation: Other firms (designers , IT firms)	0.029	(0.021)
Cooperation: Firms from the same group	-0.037	(0.023)
Cooperation: Universities or other higher education institutes	0.006	(0.023)
Cooperation: Other government or semi-private research institutes	-0.014	(0.027)
Share of Innovation costs in turnover	0.144*	(0.080)
Share of internal R&D (IR&D) in Innovation costs	0.010	(0.017)
Share of external R&D (ER&D) in Innovation costs	0.007	(0.033)
Share of conception and construction costs (CCC) in Innovation costs	-0.004	(0.024)
Share of costs induced by R&D (CIND) in Innovation costs	0.012	(0.017)
Continuous R&D	0.002	(0.013)
Public support for innovation	-0.008	(0.021)
Organizational innovation	0.029***	(0.010)
Enterprise Group	0.022	(0.015)
Size	-0.029	(0.019)
Size squared	0.003*	(0.002)
Intercept	0.042	(0.047)
Log pseudolikelihood	-67.3	
Pseudo R^2	0.42	
Sigma	0.128***	(0.005)
H0: All coeff =0	96.6***	
Industry dummies	Yes	
Number of obs	934	

Legend:* p<.10; ** p<.05;*** p<.01
Explained variable : cost reduction (%) induced by process innovation
544 left-censored observations at reducost=0, 390 uncensored observations