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BARRIERS TO INNOVATION IN SERVICES INDUSTRIES IN CANADA

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BARRIERS TO INNOVATION IN SERVICES INDUSTRIES IN CANADA

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THE SCIENCE AND INNOVATION INFORMATION PROGRAM

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 (**Science and Technology Activities and Impacts: A Framework for a Statistical Information System,** Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/english/research/scilist.htm.

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BARRIERS TO INNOVATION IN SERVICES INDUSTRIES IN CANADA

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ABSTRACT- Many studies have dealt with the conditions which promote technological innovation initiatives in Canadian firms. This study looks at innovation from another angle, i.e. the barriers to innovation. The perceived barriers to innovation in Canadian business were assessed for the communications, financial and technical services industries targeted by the second innovation survey conducted by Statistics Canada. We will emphasize a number of factors which explain the perceived barriers using data analysis and an econometric model. We will also determine to what extent some obstacles complement each other. If there is in fact complementarity, any attempt to effectively remove barriers to innovation must be based on a systems approach.

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INTRODUCTION

Innovation, which has always formed the basis for progress, has become a predominant business issue. Globalization has forced companies to constantly adapt, and has made competition fiercer than ever. The need to innovate, in terms of products, manufacturing processes or internal corporate organization, makes no special provision for firms without the know-how or the will to adapt.

This makes it all the more important to understand why some firms do not innovate, and why some firms innovate more than others. Many studies have dealt with the determining factors of innovation, and specifically of R&D. The factors most often studied have been business size, the intensity of competition, technological opportunity and the ability to benefit from innovation (see Cohen (1995) and Kleinknecht (1996) for a review of the situation). Empirical results are still fairly mixed. Yet another approach is to assess the impediments to innovation. In fact, innovation surveys do include questions about barriers as they are perceived by the responding companies. The aim of this study is to assess barriers to innovation as they are perceived by Canadian firms in the most dynamic services industries, i.e. communications, financial services and technical services, targeted by the second innovation survey conducted by Statistics Canada.

Beyond the identification of factors which explain perceived barriers to innovation, our main objective in this study is to detect complementarities between barriers, and to establish groups of impediments based on these complementarities.

There is a distinct possibility that some barriers are interrelated. For example, a lack of equity capital can be expected to lead to a lack of outside capital, given the likelihood that short-term funding capacity is linked to long-term funding capacity. In the risky area of innovation, in particular, suppliers of funds will favour, or even demand, a capital outlay on the part of innovators. The perception of high costs as a barrier to innovation is probably linked to a perceived lack of equity capital or outside capital. Likewise, a shortage of qualified staff, a lack of special equipment and funding problems can be expected to lead gradually to problems of feasibility and eventually of success as far as innovation is concerned. Other obstacles that are more institutional than technical can hamper the proper implementation of an innovation project. The frame of mind which characterizes business leadership is reflected in the calibre and skills of the prime mover, as well as in the qualifications of those who make up the team. As a result, an insufficiently qualified staff will probably lead to internal resistance to the type of momentum that produces innovation. Internal resistance leads in turn, quite naturally, to more cumbersome administrative processes.

There are two types of impact of such complementarities, one on economic policy, the other on the development of innovation surveys. If some obstacles are interdependent or re-inforce each other, it will be futile to combat them individually. Instead, a systems approach will be needed. In one sense, this is what the proponents of the concept of national innovation systems have been saying all along. An innovation system is based on a number of rules, institutions, organizations, choices of location for research and learning centres, networks of researchers and types of funding, in short on a whole array of interdependent components linked to innovation and forming a system. Our analysis will stress the essential elements of such a system as well as its limits.

Another reason for thus classifying and aggregating obstacles is related to the development of innovation surveys. In the database of the Statistics Canada innovation survey in services industries, obstacles are grouped on the basis of such criteria as risk related to feasibility, high cost, lack of availability of inputs, internal resistance within firms, legislation and regulations. [1]In their study of the data from this survey, Baldwin et al. (1998) proposed the following thematic groupings: technical and feasibility risks, financial impediments and other impediments. If such aggregates do in fact exist, it may well be that firms would have a tendency to respond in the same way to obstacles belonging to a given group, in which case the number of survey questions could very well be reduced in future, given that a certain response would be quite likely to lead to another. It will be seen below that a certain grouping can be implied simply by the way in which the questionnaire is organized. Such a classification of obstacles is not desirable since it is inspired by the survey's own logic. Following our analysis, suggestions will be made to establish a questionnaire ensuring a certain exogeneity of the relationships between questions.

Finally, obstacle complementarities and groupings identified by this analysis might serve as a reference point for future comparisons with other similar surveys, in particular at the international level.

The data are presented in the second section of this paper. In the third section, the data undergo a descriptive analysis along a few lines of variation. In the fourth section, obstacle complementarities are analyzed in terms of principal components and assessed using an ordered multivariate probit model. The concluding section summarizes the main findings of the study.

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[1] These terms match those found in the survey questionnaire itself, although the database that we were provided with did not contain three of the barriers mentioned in the questionnaire.

1. INTRODUCING THE DATABASE

This study is based on innovative enterprise data from the 1996 Survey of Innovation in Services Industries conducted by Statistics Canada. The sample included three groups of industries: communications, financial services, technical services (see Table 1).

For these groups of industries, we had 341, 90 and 1,960 firms respectively and 147 variables. Those that were taken into consideration were based on an understanding of the impediments to innovation in the three groups of industries. Table 2 provides a comparison of our database with the population of the three groups of industries under study. The representativeness of our sample was 38% for communications, 54% for financial services and 9% for technical services.

TABLE 1

Subsections for each group of industries

Group of industries	Subsections
Communications	Radio broadcasting (SIC 4811) Television broadcasting (SIC 4812) Combined radio and television broadcasting (SIC 4813) Cable television (SIC 4814) Telecommunication carriers (SIC 4821) Other telecommunication industries (SIC 4839)
Financial services	Chartered banks (SIC 7021) Trust companies (SIC 7031) Life insurers (SIC 7311)
Technical services	Computer services (SIC 7721) Computer equipment maintenance and repair (SIC 7722) Offices of engineers (SIC 7752) Other scientific and technical services (SIC 7759)

TABLE 2

Representativeness of the sample

Group of industries	Number of firms in the sample	Population of firms
Communications	341	895
Financial services	90	168
Technical services	1960	21053

Most of the innovative firms in our sample of services industries in Canada were small: 83% of the innovative firms in the communications, financial services and technical services sectors had less than 100 employees. The communications sector included the highest percentage (62%) of innovative firms having less than 20 employees (Table 3). In the financial services sector, firms were larger than in the other two sectors: 26% of them had more than 500 employees. In the technical services sector, most firms had 20 to 99 employees. Because of its predominance in the overall sample, this sector showed a distribution of firm sizes that was very close to the average distribution for the sample as a whole.

TABLE 3

Distribution of innovative firms by size (as a percentage)

Group of industries	Less than 20 employees	20 to 99 employees	100 to 499 employees	More than 500 employees
Communications	62	23	8	7
Financial services	7	34	33	26
Technical services	48	37	9	6
All three sectors	48	35	10	7

2. PERCEIVED BARRIERS TO INNOVATION: DESCRIPTIVE ANALYSIS

This section will examine how the barriers to innovation are perceived by respondents, given their industrial affiliation, their size, their research and development expenses and the experienced intensity of competition.

THE PERCEIVED BARRIERS TO INNOVATION ACCORDING TO THE SECTOR

In the innovation survey, the answers for various impediments to innovation are arranged on a Likert scale of (1) to (6), where (1) represents an insignificant impediment and (5) represents a crucial impediment. Level (6) is intended for respondents who feel the question is not relevant. Table 4 summarizes the average perception of barriers to innovation (arithmetic mean for the 13 barriers) in each of the sectors. In the three sectors, on average, 25% of the respondents found the barriers listed not relevant. Most of the answers fell in the neutral category “moderately significant”. The percentage of answers in categories (4) and (5) was fairly close to the percentage of answers in categories (1) and (2). On the other hand, only 6% of the respondents felt the barriers were crucial, whereas 13% considered them insignificant. The distribution was not very different from one sector to the other. It was slightly higher in the technical services sector, more moderate in the financial services sector and more often "not relevant" in the communications sector.

TABLE 4

Distribution of perceived barriers by level of intensity and by sector

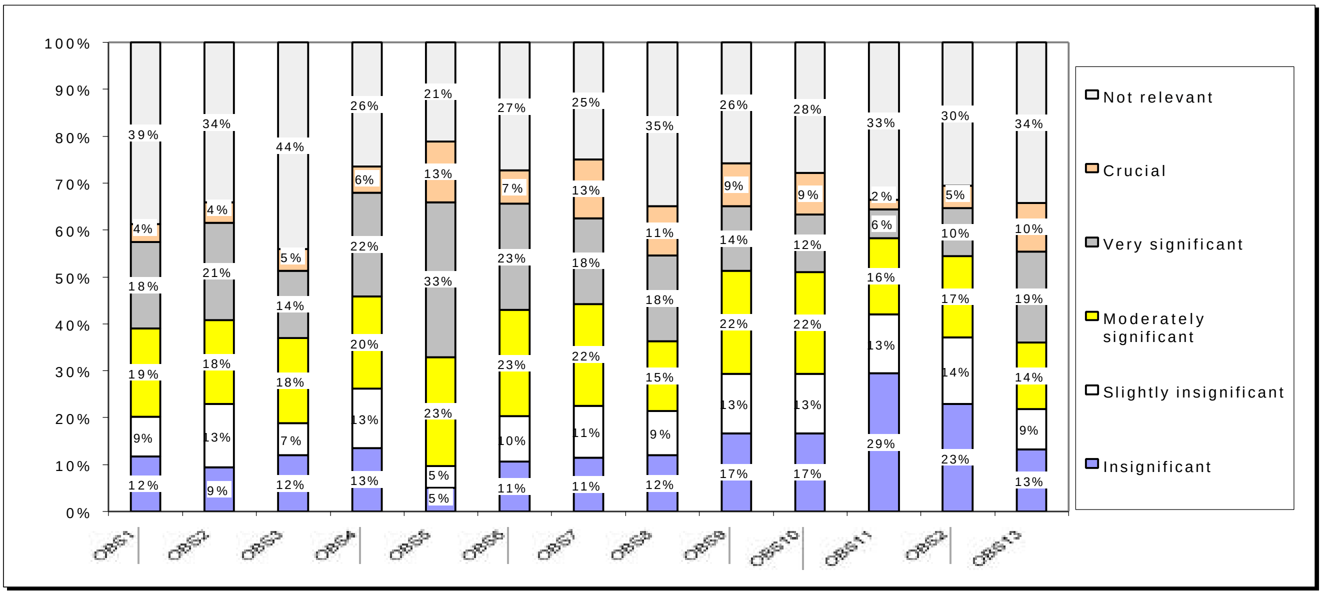
	Not relevant (6)	Crucial (5)	Very significant (4)	Moderately significant (3)	Slightly insignificant (2)	Insignificant (1)
Communications	31%	8%	18%	19%	11%	14%
Financial services	25%	3%	19%	24%	18%	11%
Technical services	19%	8%	23%	22%	14%	14%
All three sectors	25%	6%	20%	22%	14%	13%

As an aid to viewing the significance given to each of the 13 barriers to innovation, Charts 2.1 to 2.3 show, for each of the sectors, the distribution of answers by level of intensity.

Communications sector

Chart 2.1

Distribution by level of intensity of each obstacle to innovation in the communications sector (as a percentage)



As was mentioned previously, almost one third of the firms considered the questions related to obstacles not relevant. Adding the percentages for both insignificant and not relevant, we note that 45% of the firms in this sector perceived barriers to innovation of little significance. The least significant obstacles were those related to risk (OBS1 to 3).

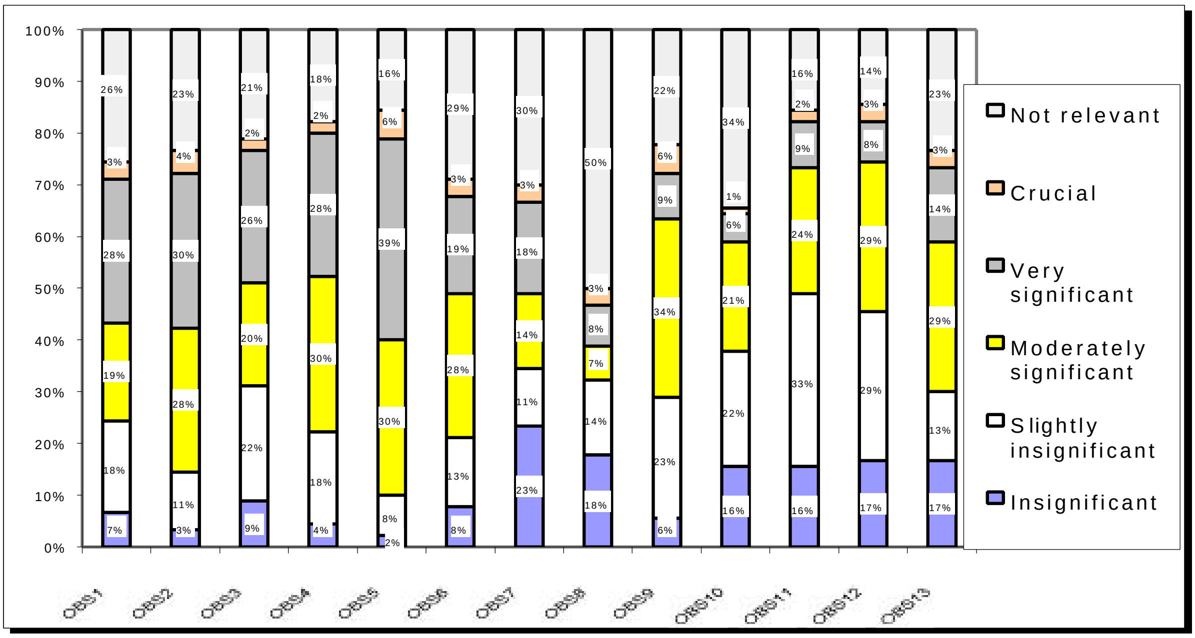
A further observation, which will be seen to apply also to the other two sectors, is that the most important barrier to innovation was the high cost of innovation projects (OBS5). This was a very significant impediment for close to 33% of the firms, and for 13% of them it was a crucial impediment. This was also noted by J. Baldwin et al. (1998). The most significant obstacles were those related to costs and capital (OBS4 to 8) and those related to legislation and regulations (OBS13). For these barriers, the sum of answers (4) and (5) exceeded 25% of all answers.

Financial services sector

The striking feature of this sector was the low percentage of answers in the crucial category (3% on average) as compared to the other two sectors. The financial services sector felt moderately affected by impediments to innovation as a whole. The most significant impediments in this sector seemed to be barriers 1 to 5, again with cost as the principal factor. The lack of funds, staff and willingness to innovate did not seem to represent major barriers, nor for that matter legislation and regulations. If financial institutions were cautious about new technological developments, this caution seemed to be linked more to feasibility risks and market outlets than to any real risk of lack of funds.

Chart 2.2

Distribution by level of intensity of each obstacle to innovation in the financial services sector (as a percentage)



Technical services sector

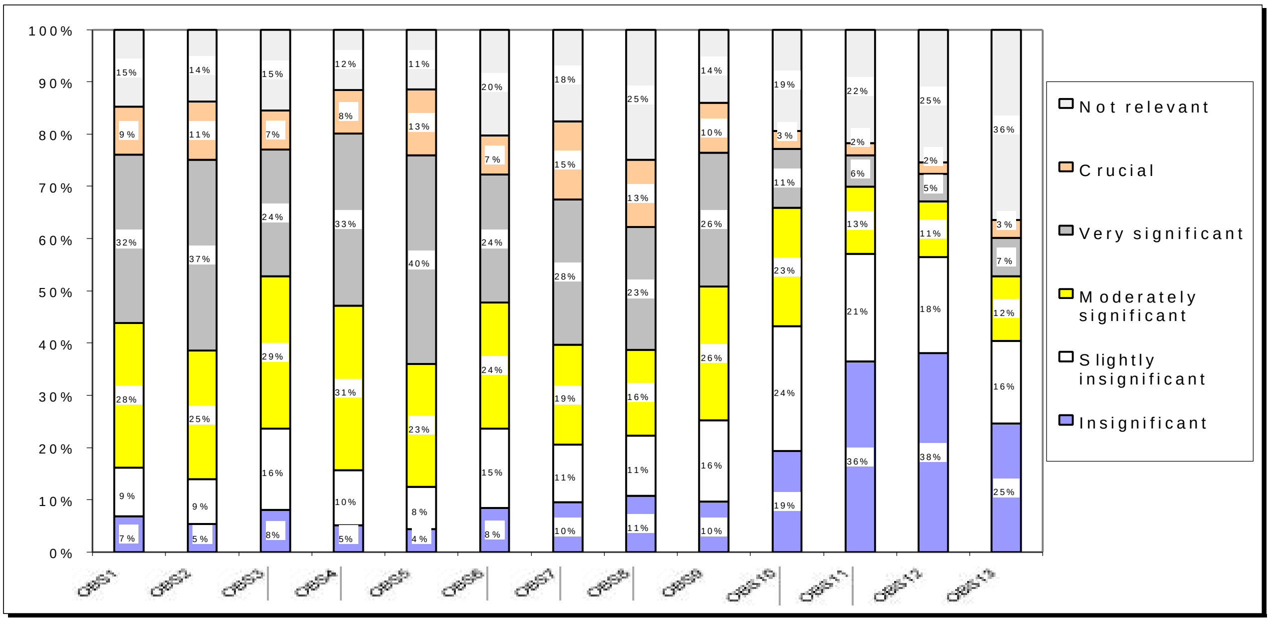
Of the three sectors targeted in our study, the technical services sector was without a doubt the one in which barriers to innovation were felt most strongly. This sector was also the one in which the response "not relevant", i.e. category 6, was lowest. Generally, barriers were perceived more strongly in this sector.

Categories (4) and (5) represented 30% to 50% of the answers to barriers 1 to 9. The lack of equipment, internal resistance to change and the regulatory environment were not perceived as impediments.

As compared to the other two sectors, barriers 7 to 9, i.e. the lack of equity capital, the lack of outside capital and the shortage of qualified staff, were definitely perceived as impediments.

Chart 2.3

Distribution by level of intensity of each obstacle to innovation in the technical services sector (as a percentage)



As compared to the other two sectors, the perception of risks related to the legal environment (OBS13) was also much less pronounced in the technical services sector. In fact, only 22% of the firms in this sector reported that this barrier was crucial, very significant or moderately significant, as compared to 45% of the firms in the financial services sector and 43% of those in communications. This may be due to the fact that the computer services industry, and in particular the information highway, are not yet specifically regulated.

In conclusion, for a fairly high percentage of respondents, the barriers to innovation contained in the survey were deemed relevant. The major obstacle in all three sectors was the high cost related to innovation. Some barriers seemed to affect certain sectors more than others. Thus, the communications sector was seen to be more sensitive to legal impediments, while the technical services sector was more affected by barriers related to insufficiently qualified staff, and the financial services sector was more concerned about risks related to innovation. Barriers to innovation as a whole had less of an impact on the financial services sector, which, it will be remembered, had the highest rate of large firms.

THE PERCEPTION OF BARRIERS TO INNOVATION ACCORDING TO THE SIZE OF FIRMS, ALL SECTORS INCLUDED

For 13% of the firms having less than 100 employees, impediments to innovation were perceived on average as very significant to crucial, whereas this figure dropped to 2.5% for firms having more than 100 employees. As the size of firms increased, impediments to innovation were perceived less strongly (Table 5).

It is interesting to note that the significance granted to barriers was relatively independent of the size of firms. The most significant obstacle, both for small and large firms, remained the high cost. Baldwin and Lin (1999) reported the same finding on the basis of data from the Canadian Survey on the Adoption of Advanced Technology. Two groups of impediments were identified: on the one hand the lack of funding and qualified staff, which quickly dropped in significance as the size of firms increased, and on the other the risk related to feasibility and success, which also decreased in perceived significance, though less markedly, as size increased. The group of obstacles perceived as relatively less significant included the lack of equipment, internal resistance to innovation, administrative delays and the regulatory environment. Among these, the lack of equipment, and legislation and regulations, seemed to be the most significant obstacles for firms of smaller size.

TABLE 5

Proportion of respondents who felt obstacles were very significant or crucial (as a percentage)

	Firms of less than 20 employees	Firms of 20 to 99 employees	Firms of 100 to 499 employees	Firms of more than 500 employees
OBS1- High risk related to the feasibility of an innovation project	17	14	4	3
OBS2 – High risk related to succcessful marketing of the innovation	19	16	5	4
OBS3 – Innovation is easily copied by other firms	15	10	3	2
OBS4 – Difficulty of predicting the costs of innovation	17	14	5	3
OBS5 – High costs of innovation projects	23	18	5	5
OBS6 – Long depreciation period for innovation	16	10	3	2
OBS7 – Lack of equity capital for the implementation of innovative projects	21	15	3	2
OBS8 – Lack of outside capital for innovation projects	18	12	2	2
OBS9 – Shortage of qualified staff for innovation projects	14	13	3	2
OBS10 – Lack of equipment for the implementation of innovation projects	8	6	1	0
OBS11 – Internal resistance to innovation	3	4	1	1
OBS12 – Prolonged administrative processing or authorization to implement innovation projects	4	3	1	1
OBS13 – Legislation and regulations having an impact on innovation projects	7	5	1	1

THE PERCEPTION OF BARRIERS TO INNOVATION BASED ON THE PRESENCE OR ABSENCE OF R&D

As there were no data on non-innovative firms, we examined firms that conducted research and development to see whether they responded differently to obstacles from those which did not conduct such activities. To do so, we recorded in Tables 6 and 7 the answers to all six categories of perceived barriers to innovation for firms conducting R&D and for those which did not as a percentage of the total number of firms included in each group.

TABLE 6

Distribution of answers by level of perception of obstacles to innovation, for firms conducting R&D (as a percentage)

	FIRMS CONDUCTING R&D					
Level of Perception	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
OBS1- High risk related to the feasibility of an innovation project	6	10	28	37	11	8
OBS2 – High risk related to succcessful marketing of the innovation	4	9	25	42	13	7
OBS3 – Innovation is easily copied by other firms	8	17	31	27	8	9
OBS4 – Difficulty of predicting the costs of innovation	4	11	33	37	9	6
OBS5 – High costs of innovation projects	3	8	25	45	15	5
OBS6 – Long depreciation period for innovation	9	15	28	27	8	14
OBS7 – Lack of equity capital for the implementation of innovative projects	10	11	20	30	17	12
OBS8 – Lack of outside capital for innovation projects	10	12	18	26	15	19
OBS9 – Shortage of qualified staff for innovation projects	10	16	27	27	11	9
OBS10 – Lack of equipment for the implementation of innovation projects	21	26	24	12	4	14
OBS11 – Internal resistance to innovation	38	23	12	6	2	18
OBS12 – Prolonged administrative processing or authorization to implement innovation projects	40	20	12	6	2	20
OBS13 – Legislation and regulations having an impact on innovation projects	27	18	15	9	4	28

TABLE 7

Distribution of answers by level of perception of obstacles to innovation, for firms not conducting R&D (as a percentage)

	FIRMS NOT CONDUCTING R&D					
Level of Perception	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
OBS1- High risk related to the feasibility of an innovation project	11	10	22	19	3	36
OBS2 – High risk related to succcessful marketing of the innovation	9	10	21	20	5	35
OBS3 – Innovation is easily copied by other firms	11	11	21	16	4	38
OBS4 – Difficulty of predicting the costs of innovation	10	12	24	22	6	27
OBS5 – High costs of innovation projects	7	7	22	29	9	26
OBS6 – Long depreciation period for innovation	9	13	18	20	6	35
OBS7 – Lack of equity capital for the implementation of innovative projects	11	11	19	19	9	32
OBS8 – Lack of outside capital for innovation projects	13	10	13	16	8	41
OBS9 – Shortage of qualified staff for innovation projects	12	15	23	16	6	28
OBS10 – Lack of equipment for the implementation of innovation projects	16	16	20	11	4	34
OBS11 – Internal resistance to innovation	28	15	17	6	2	32
OBS12 – Prolonged administrative processing or authorization to implement innovation projects	27	16	13	6	3	36
OBS13 – Legislation and regulations having an impact on innovation projects	16	9	11	11	5	48

An analysis of Tables 6 and 7 shows that firms conducting R&D perceived obstacles to innovation more strongly. For such firms, most of the answers were included in categories (3) to (5). For firms not conducting R&D, category (6) was predominant, which means that for these firms most of the obstacles to innovation were not relevant. The structure of answers was all the more different as the perceived obstacles were significant.

It could have been assumed that those firms which perceived obstacles strongly would be those that did not conduct research and development. The opposite seems to have prevailed i.e. the perception of obstacles increased as more R&D was conducted. It is in fact plausible that certain problems are not effectively encountered until firms face them. This type of observation was also made by Baldwin and Lin (1999), who reported increased relationships between the level of use of advanced technologies in Canada and the perception of impediments.

THE PERCEPTION OF BARRIERS TO INNOVATION BASED ON THE INTENSITY OF COMPETITION

Finally, we compared the answers about impediments to innovation for various levels of perception of competition. Two groups of firms were chosen for this, i.e. those which consider the environment as less competitive than the average for the sample, and the others. The competitive environment was defined in terms of seven factors contained in the innovation survey questionnaire: price, flexibility in responding to customer needs, quality, customer service, customization of products, offering a wide range of related products, frequently introducing new/improved products. For these seven criteria, the firms rated the intensity of competition in their respective sectors on a scale of 1 to 5. To separate our sample into two groups, we calculated an average for the level of response to the seven factors for the sample as a whole, and compared the grand mean to the mean level of response for each of the firms. Note that the grand mean was 3.4, and that 766 firms were included in the "weak" group as compared to 1,459 in the "strong" group. We eliminated 166 firms, 47 of which did not answer any questions, and 119 of which found the questions not relevant.

Our first finding was that only one firm in three was included in the group that considered the competitive environment, as we defined it, to be weak. The grand mean which we took as a reference corresponded to a level of perception of the competitive environment that could be qualified as moderately strong. This comment is significant, since even in the weak group some firms could have an average exceeding 3.0, which means they nevertheless considered the market to be competitive. As a rule, firms which showed less sensitivity to the competitive environment did so either because they had no direct competitors, or because they operated in areas where the frequency of technological change was low.

Table 8 shows that firms which faced less competition had a tendency to consider questions related to impediments not relevant, or the impediments themselves insignificant, whereas firms facing more competition had a tendency to consider obstacles more significant. These findings might indicate that competition is an incentive to innovate, and that the most innovative firms are those which perceive barriers to innovation most strongly, or simply that the obstacles to innovation are strongest when competition is at its highest.

TABLE 8

Distribution of answers related to the perception of obstacles to innovation according to the intensity of competition

	Not relevant (6)	Crucial (5)	Very significant (4)	Moderately significant (3)	Slightly insignificant (2)	Insignificant (1)
Weak competition	25%	7%	19%	20%	14%	16%
Strong competition	17%	9%	25%	23%	14%	13%

If we take a last look at the statistics which describe the obstacles to innovation (Table 9), we notice that the high cost of innovative projects represented on average the most strongly perceived barrier, and that obstacles 11 to 13 (internal resistance to innovation, longer administrative procedures, and legislation and regulations) were the impediments of least significance to respondents. Answers varied considerably for the lack of equity capital (OBS7), and were relatively consistent for the shortage of qualified staff (OBS9) and the internal structure of firms (OBS11 and OBS12).

TABLE 9

Statistics describing obstacles to innovation

Obstacles	Mean	Variance	Minimum	Maximum
OBS1- High risk related to the feasibility of an innovation project	2.89	1.72	1	5
OBS2 – High risk related to succcessful marketing of the innovation	3.04	1.70	1	5
OBS3 – Innovation is easily copied by other firms	2.71	1.62	1	5
OBS4 – Difficulty of predicting the costs of innovation	2.99	1.48	1	5
OBS5 – High costs of innovation projects	3.25	1.55	1	5
OBS6 – Long depreciation period for innovation	2.66	1.74	1	5
OBS7 – Lack of equity capital for the implementation of innovative projects	2.88	2.07	1	5
OBS8 – Lack of outside capital for innovation projects	2.61	1.48	1	5
OBS9 – Shortage of qualified staff for innovation projects	2.78	1.31	1	5
OBS10 – Lack of equipment for the implementation of innovation projects	2.19	1.40	1	5
OBS11 – Internal resistance to innovation	1.77	1.12	1	5
OBS12 – Prolonged administrative processing or authorization to implement innovation projects	1.72	1.12	1	5
OBS13 – Legislation and regulations having an impact on innovation projects	1.88	1.48	1	5

3. COMPLEMENTARITY AMONG BARRIERS TO INNOVATION

The descriptive analysis found in the preceding section shows that the obstacles to innovation seem to be linked to the size of firms, to their sector of affiliation and to the intensity of the competition they experience. Furthermore, obstacles seem to be perceived differently depending on whether or not the firms engage in R&D. We noticed that obstacles seem to form groups, and that these groups do not necessarily correspond to the categories defined in the survey questionnaire.

This leads us to the very heart of our research. Is there a pattern of complementarity between obstacles? In other words, which obstacles go together? Which categories of barriers are complementary? To answer these questions, we examined the binary correlations between answers related to obstacles. Principal component analysis was then used to identify groups of barriers. Next, the causal factors for the perception of obstacles were analyzed econometrically to discover correlations between perceived obstacles on the basis of the impact of size, sector, competition, and research and development. We limited ourselves to these four explanatory variables as they were the only ones available in the survey which seemed to us to be exogenous with respect to the perception of obstacles.

TABLE 10
Correlations between obstacles to innovation

	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12
OBS2	**0.74**											
OBS3	**0.43**	**0.48**										
OBS4	**0.57**	**0.52**	**0.40**									
OBS5	**0.57**	**0.53**	0.33	**0.69**								
OBS6	**0.45**	**0.43**	0.32	**0.51**	**0.61**							
OBS7	**0.41**	0.38	0.31	0.39	**0.47**	**0.45**						
OBS8	0.37	0.36	0.29	0.34	**0.40**	0.36	**0.81**					
OBS9	0.38	0.35	0.31	**0.42**	0.35	0.26	0.34	0.31				
OBS10	0.27	0.21	0.24	0.31	0.29	0.31	**0.42**	0.39	**0.48**			
OBS11	0.15	0.13	0.10	0.20	0.17	0.11	0.10	0.10	0.26	0.27		
OBS12	0.13	0.12	0.09	0.18	0.17	0.13	0.07	0.07	0.17	0.25	**0.58**	
OBS13	0.17	0.14	0.16	0.17	0.18	0.20	0.17	0.17	0.15	0.24	0.21	0.25

In bold characters: correlations greater than or equal to 0.40

At first sight, the binary correlations shown in Table 10 indicate that the answers related to obstacles 11 to 13 do not strongly correlate with those of other questions. The internal resistance to innovation and the complexity of decision-making, on the other hand, seem to go together (0.58 between OBS11 and OBS12). A second impression that can be gathered from the matrix of simple correlations is the positive correlation between all pairs of impediments. For 22 pairs out of 78, the coefficient of correlation is greater than 0.40, and nine of them exceed the threshold of 0.50, while two exceed the threshold of 0.70. The two correlations which predominate are the one between the risks related to feasibility and the risks related to project success (0.74 between OBS1 and OBS2) and the one between the lack of equity capital and the lack of outside capital (0.81 between OBS7 and OBS8). On the one hand, technical uncertainty has an impact on sales. On the other hand, firms which find it difficult to come up with internal financing might be the same firms which find it difficult to obtain outside funding. Another interesting finding is that, as a rule, the correlations diminish as we move away from the diagonal. This might reflect a proper choice of obstacle categories in the questionnaire, but it could also indicate bias in the answers because of the order in which questions appear.

COMPLEMENTARITY BETWEEN BARRIERS TO INNOVATION: CONSIDERING THE INDIVIDUAL IMPACT

As the assessments are subjective, it is quite possible that respondents are biased in their own assessment of the significance of obstacles, and that they have a tendency, as a result of either laziness or uncertainty, to answer certain questions in the same way. For example, some respondents might be in the habit of answering near the extremes of the scale. To overcome this situation, which could obviously bias the results, we transformed the answers into deviations from the individual mean for the answers of each respondent to the 13 obstacles, and we repeated the statistical analysis using these new data. Using a quintile distribution of the variance of individual answers to the 13 obstacles, we confirmed that there is indeed an individual impact: the quintiles of the distribution were 0.75, 1.10, 1.53, 2.07 and 4.10 respectively. Thus 60% of the respondents showed a variance for the 13 answers that was equal to 1.53 or less. Practically, this means answers of the type (1, 2, 2, 2, 2, 2, 3, 4, 4, 4, 4, 4, 5) or (1, 1, 2, 3, 3, 3, 3, 3, 3, 3, 4, 5, 5), in other words a lot of identical answers.

The correlations between barriers in Table 11 based on data expressed in deviations from the individual mean provided a clearer picture of complementarities and groupings of obstacles. The positive correlations point to answers that were, generally, jointly above or below the mean for individual answers. The negative correlations, on the other hand, indicate answers that deviated from the mean. The risks related to feasibility and success (OBS1 and 2) seemed to be aimed in the same direction, and the same can be said for the risk of being copied, the difficulty of predicting costs and the magnitude of costs (OBS3 to 5). Answers were similar for the three obstacles related to cost (OBS4 and 5), and the same can be said for sources of funding (OBS7 and 8), shortages of staff and equipment (OBS9 and 10), and the impediments due to internal or external governance of firms (OBS10 to 12). The other obstacles did not seem to be complementary. Specifically, commercial success did not seem to be linked to the availability of special equipment (OBS2 and 10), and the lack of equity capital had no bearing on obstacles to innovation within a firm (OBS7, 11 and 12).

Table 11 shows the obstacles aggregated on the basis of positive correlations. It is not surprising to find strong correlations between impediments included within the same category in the questionnaire (see Appendix 2). Of greater interest is the finding that there are correlations between different categories. An example is the correlation between risks related to feasibility or success (OBS1 and 2) and between the unpredictability or magnitude of costs (OBS4 and 5). Uncertainty about project management will probably lead to additional costs, for which funding must be found. It is also possible that the perceived risk increases as the cost involved reaches higher levels. Binary correlations must be interpreted cautiously. A positive correlation between two obstacles says nothing about the causal link between them. It may be that the relationship is due to a third variable which strongly impacts on the binary relationship. For this reason, we provide below a modified analysis of the correlations between obstacles based on a certain number of common explanatory variables. First, however, we would like to examine the results of obstacle aggregation based on a principal component analysis of the data.

TABLE 11
Correlations between obstacles to innovation (in deviations from the individual mean)

	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12
OBS2	**0.50**											
OBS3	0.01	0.13										
OBS4	0.12	0.05	-0.04									
OBS5	0.11	0.07	-0.17	0.34								
OBS6	-0.04	-0.04	-0.10	0.07	0.25							
OBS7	-0.15	-0.17	-0.16	-0.20	-0.06	-0.01						
OBS8	-0.17	-0.20	-0.15	-0.23	-0.13	-0.12	**0.67**					
OBS9	-0.10	-0.13	-0.06	-0.04	-0.18	-0.23	-0.14	-0.15				
OBS10	-0.29	**-0.35**	-0.14	-0.21	-0.28	-0.13	-001	-0.01	0.18			
OBS11	-0.27	-0.26	-0.14	-0.16	-0.24	-0.24	**-0.33**	-0.28	0.02	0.08		
OBS12	-0.28	-0.24	-0.13	-0.18	-0.21	-0.19	**-0.35**	-0.29	-0.09	0.06	**0.57**	
OBS13	-0.23	-0.22	-0.07	-0.21	-0.22	-0.12	-0.22	-0.17	-0.12	0.02	0.15	0.20

In bold characters: correlations greater than or equal to 0.30

Bounded areas show possible groupings of obstacles.

PRINCIPAL COMPONENT ANALYSIS (OF DATA IN DEVIATIONS FROM THE INDIVIDUAL MEAN)

The purpose of this principal component analysis was not so much to merge the 13 obstacles into a few units, but rather to discover those which might be aggregated in such a way that their consolidation would greatly help to explain the variance of answers for obstacles to innovation. If, within these groupings of principal components, there are obstacles having the same sign (whatever it is), they can be said to make a similar contribution in explaining the total variation of answers related to the obstacles. In accordance with Kaiser's criterion, which retains the principal components whose corresponding characteristic value is greater than 1, we retained three factorial designs reflecting those factors which accounted for the greatest variance of all individual answers related to obstacles. The factorial designs were named after the variables having the greatest weight in creating the factor. Thus, the first factor was called “Risk and internal resistance” because variables OBS1, OBS2, OBS11 and OBS12 were the main contributors to this factorial design (see Table 12). The principal component analysis carried out on data in deviations from the individual mean (Table 12) confirmed the analysis of binary correlations (Table 11). Obstacles linked to risks (of feasibility, of success and, to a lesser extent, of being copied) (OBS1, 2 and 3) formed a unit, as did the lack of internal and outside funding (OBS7 and 8), the high cost (OBS5 and 6) and internal impediments within the firm (OBS11 and 12). These four groups of factors characterized the three principal components explaining 50% of the variance of deviating answers. These same groups of obstacles were already apparent in our first analysis of the raw data in section 4.

Principal component analysis was used to validate the aggregation of obstacles into pairs of complements. The econometric approach will now be used to examine the correlations once the impact of such variables as size, sector of affiliation and intensity of competition has been neutralized.

TABLE 12

Principal component analysis of obstacles to innovation that deviate from the individual mean

Obstacles	Design 1 Risks and internal resistance	Design 2 Risks and lack of funds	Design 3 Risks and high costs
OBS1- High risk related to the feasibility of an innovation project	**-0.34**	**0.25**	0.29
OBS2 – High risk related to succcessful marketing of the innovation	**-0.33**	**0.26**	**0.37**
OBS3 – Innovation is easily copied by other firms	-0.06	0.12	**0.40**
OBS4 – Difficulty of predicting the costs of innovation	-0.23	0.25	-0.28
OBS5 – High costs of innovation projects	-0.30	0.15	**-0.48**
OBS6 – Long depreciation period for innovation	-0.20	0.02	**-0.47**
OBS7 – Lack of equity capital for the implementation of innovative projects	-0.16	**-0.57**	-0.02
OBS8 – Lack of outside capital for innovation projects	-0.11	**-0.57**	0.05
OBS9 – Shortage of qualified staff for innovation projects	0.13	0.00	0.25
OBS10 – Lack of equipment for the implementation of innovation projects	0.28	-0.20	0.03
OBS11 – Internal resistance to innovation	**0.44**	0.19	-0.06
OBS12 – Prolonged administrative processing or authorization to implement innovation projects	**0.43**	0.20	-0.12
OBS13 – Legislation and regulations having an impact on innovation projects	0.29	0.06	-0.05
Representativeness (%)	21	17	12
Representativeness (accrued %)	21	38	49

ECONOMETRIC APPROACH TO THE COMPLEMENTARITY OF OBSTACLES TO INNOVATION (IN DEVIATIONS FROM THE INDIVIDUAL MEAN)

Another strategy used to detect complementarities between barriers to innovation is to estimate a structural model in which the perception of obstacles is explained by a certain number of variables. Once the impact of these variables has been neutralized, the residual correlation between the obstacles can be assessed. Specifically, we will be assessing an ordered multinomial probit model, in which a link is established between the categorized answers to perceived barriers to innovation and a number of implementations within certain intervals of a latent variable. The econometric model and its estimation procedure are described in Appendix 1. The presumably exogenous explanatory variables used for this model were industrial affiliation, the size of firms, the intensity of the perceived competition (Nc) and whether or not the firm engaged in research and development (R&D). All these variable were dichotomous with the exception of the intensity of competition, which assumed values between 1 and 5. Note that we also assessed the model using a dichotomous variable for Nc, using the value 0 or 1 depending on whether the firm perceived the intensity of competition more or less strongly than the grand mean of firms within the sample. The results obtained for this latter specification had the same signs and a closeness of fit only slightly below the final specification that was retained. Note also that, for the sake of consistency with the previous analysis, we grouped the “not relevant” and “insignificant” answers into a single category. The categories of answers therefore covered a scale of 1 to 5, where 5 represented the highest level. An analysis based on 6 categories, where the sixth represented the first group, yielded very similar results. It was therefore deemed superfluous to use a sixth category. The data in deviations from the individual mean were no longer integers, but they assumed a finite number of values. We decided to classify them into five categories, as was done for the original data. The limits separating the categories were -2.4, -0.8, 0.8 and 2.4.

The reference group in Table 13 included large firms in the technical services sector. The coefficients for dichotomous variables "industry" and "size" show the deviation from the thresholds of the distribution of latent variables for firms of other industries and other sizes. Obstacles 1 to 9 tended to be perceived less strongly than the other obstacles in the communications sector and the financial services sector, and the reverse was true for obstacles 10 to 13, i.e. obstacles linked to the lack of special equipment, to internal governance and to the legal environment were perceived more strongly than the other obstacles. Small firms had lower scores for obstacles 1, 2, 4, 5 and 11 and 12, and higher scores for the other obstacles. Risks related to feasibility and success, the uncertainty about costs, high costs and internal impediments to innovation were thus perceived more strongly than the other obstacles by large firms. On the other hand, funding sources (equity capital, depreciation and outside capital), the lack of equipment and the legal environment were perceived more strongly as barriers to innovation than others by small firms. Copying and the shortage of qualified staff were not perceived differently by firms of varying size. Finally, competitive pressures increased the perception of risk (technical, commercial and copying) as obstacles, but reduced the severity of problems linked to governance and access to outside capital. Firms engaging in R&D perceived more strongly those obstacles that were linked to risks, costs and funding problems, and less strongly those linked to lack of equipment and to the firm’s internal and external environment.

Using estimates from Table 13, we correlated the generalized residuals for each equation. Table 14 highlights mostly intra-group complementarities, the groups being those defined in the survey questionnaire. In other words, there was some complementarity between the obstacles related to various types of risk (feasibility, marketing, potential appropriation), between those related to costs (high costs, difficulty of predicting them, depreciation period), between the lack of equity capital and the lack of outside capital, between the shortage of qualified staff and the lack of special equipment, and between internal resistance to innovation and administrative impediments to the implementation of innovation projects.

In addition to these intra-group complementarities, we detected two types of inter-group complementarities. Costs and risks seemed to go together, as did problems of internal and external governance. We cannot conclude that these high risks lead to costs or vice versa, or that increased regulations are accompanied by increased internal resistance to change. Our analysis simply suggests that these pairs of seemingly independent obstacles form a unit.

Taking into account the four explanatory variables of perceived obstacles did not significantly change the correlations observed between these obstacles (comparing Tables 11 and 14). It is as if our model had helped us explain more or less the same fraction of variance for answers to each obstacle. It would therefore seem that the key to understanding correlations must be found elsewhere.

Finally, we calculated the correlations between residuals on the basis of separate estimates for each industry (not given here since the estimates were often of little significance). This provided a picture of the correlations that was quite similar to that in Table 14 for the technical services sector (the most significant of the three), but more complementarities for the other two sectors (Tables 15 and 16). If we limit ourselves to correlations significantly different from zero, the communications sector is not very different from the technical services sector. On the other hand, the financial services sector includes more complementarities, especially between obstacles related to internal and external governance and other obstacles.

<u>TABLE 13</u>

<u>Ordered multinomial probit model of obstacles to innovation (in deviations from the individual mean)</u>

		Dependent variables												
		OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12	OBS13
Explanatory variables	IND1	**-0.45**	**-0.45**	**-0.39**	**-0.41**	0.01	0.09	-0.03	0.007	**-0.27**	**0.15**	-0.02	**0.36**	**0.72**
		(-6.22)	**(-5.76)**	**(-5.43)**	**(-5.76)**	(0.23)	(1.23)	(-0.48)	(0.10)	**(-3.51)**	**(2.06)**	(-0.27)	**(4.85)**	**(10.14)**
	IND2	**-0.36**	**-0.39**	-0.02	-0.19	-0.05	-0.05	**-0.34**	**-0.48**	-0.21	-0.022	**0.44**	**0.49**	**0.69**
		(-2.56)	**(-2.99)**	(-0.18)	(-1.3)	(-0.35)	(-0.38)	**(-2.66)**	**(-3.46)**	(-1.51)	(-0.16)	**(3.08)**	**(3.82)**	**(5.01)**
	Size1	**-0.42**	**-0.34**	0.07	**-0.24**	**-0.48**	**0.24**	**0.49**	**0.35**	-0.009	**0.44**	**-0.55**	**-0.91**	**0.23**
		(-3.53)	**(-2.94)**	(0.65)	**(-2.27)**	**(-4.0)**	**(2.35)**	**(5.66)**	**(4.03)**	(-0.09)	**(4.36)**	**(-5.61)**	**(-9.75)**	**(2.04)**
	Size2	**-0.35**	**-0.28**	-0.11	-0.19	**-0.47**	0.06	**0.42**	**0.20**	0.11	**0.48**	**-0.38**	**-0.77**	**0.27**
		(-2.93)	**(-2.44)**	(-1.03)	(-1.74)	**(-3.89)**	(0.57)	**(4.85)**	**(2.34)**	(1.12)	**(4.55)**	**(-3.8)**	**(-8.25)**	**(2.29)**
	Size3	**-0.27**	-0.01	-0.09	-0.20	**-0.67**	0.15	0.02	-0.024	0.11	**0.29**	**-0.29**	**-0.64**	**0.37**
		(-1.96)	(-0.08)	(-0.72)	(-1.64)	**(-4.87)**	(1.18)	(0.19)	(-0.21)	(0.96)	**(2.35)**	**(-2.45)**	**(-5.46)**	**(2.84)**
	Nc	**0.10**	**0.14**	**0.07**	0.03	0.004	0.02	-0.05	**-0.08**	0.04	-0.03	**-0.12**	**-0.12**	**-0.07**
		(3.55)	**(4.8)**	**(2.59)**	(1.27)	(0.16)	(0.73)	(-1.68)	**(-2.92)**	(1.56)	(-1.16)	**(-4.41)**	**(-4.33)**	**(-2.37)**
	R&D	**0.30**	**0.28**	**0.12**	**0.11**	**0.18**	-0.04	**0.16**	**0.16**	0.007	**-0.29**	**-0.58**	**-0.47**	**-0.27**
		(5.72)	**(5.54)**	**(2.32)**	**(2.07)**	**(3.3)**	(-0.8)	**(2.95)**	**(3.06)**	(0.13)	**(-5.31)**	**(-10.8)**	**(-8.82)**	**(-5.29)**
Constant and thresholds	Alpha 1	**-2.93**	**-2.82**	**-2.30**	**-3.25**	**-3.48**	**-2.41**	**-3.11**	**-2.54**	**-2.63**	**-2.28**	**-3.18**	**-3.36**	**-2.01**
		(-12.39)	**(-11.71)**	**(-12.6)**	**(-11.4)**	**(-12.62)**	**(-12.17)**	**(-9.77)**	**(-14.3)**	**(-13.0)**	**(-12.98)**	**(-19.35)**	**(-20.5)**	**(-11.6)**
	Alpha 2	**-1.11**	**-1.0**	**-0.65**	**-1.55**	**-2.09**	**-0.73**	**-0.72**	**-0.65**	**-0.77**	**-0.32**	**-1.17**	**-1.31**	-0.001
		(-6.54)	**(-6.11)**	**(-4.26)**	**(-9.81)**	**(-12.01)**	**(-4.61)**	**(-4.77)**	**(-4.46)**	**(-4.97)**	**(-2.09)**	**(-7.67)**	**(-8.82)**	(-0.01)
	Alpha 3	**0.61**	**0.64**	**0.89**	**0.37**	-0.24	**0.89**	**0.67**	**0.63**	**0.69**	**1.38**	0.29	0.06	**1.21**
		(3.68)	**(3.95)**	**(5.8)**	**(2.36)**	(-1.42)	**(5.69)**	**(4.49)**	**(4.38)**	**(4.51)**	**(8.61)**	(1.89)	(0.41)	**(7.19)**
	Alpha 4	**2.66**	**2.55**	**2.43**	**2.54**	**1.87**	**2.62**	**2.59**	**2.45**	**2.25**	**2.95**	**1.59**	**1.39**	**2.44**
		(12.84)	**(14.32)**	**(14.8)**	**(14.01)**	**(10.58)**	**(15.63)**	**(16.92)**	**(15.34)**	**(13.52)**	**(14.89)**	**(8.01)**	**(6.84)**	**(12.95)**
# obs.		2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205
Likelihood ratio		51.39	64.09	62.52	55.61	47.65	19.17	86.00	81.90	28.51	83.36	97.50	52.65	11.58
% of correct prediction		56.87	50.79	54.92	59.00	52.56	57.91	48.39	46.84	52.60	56.14	54.50	56.64	52.56

IND1 and IND2 represent, respectively, the communications sector and the financial services sector.

Size1, Size2 and Size3 represent variables corresponding to firms of less than 20 employees, of 20 to 99 employees and of 100 to 499 employees.

Nc is the variable for the perceived mean intensity of competition.

The Student statistic is provided between parentheses. Significant values are shown in bold characters.

TABLE 14

Correlations between generalized residuals (in deviations from the individual mean), all sectors included

	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12
OBS2	**0.48**											
OBS3	0.042	**0.14**										
OBS4	**0.11**	0.05	-0.006									
OBS5	**0.13**	**0.13**	**-0.11**	**0.38**								
OBS6	-0.005	**0.008**	**-0.09**	**0.13**	**0.31**							
OBS7	**-0.12**	**-0.09**	**-0.11**	**-0.16**	-0.03	0.03						
OBS8	**-0.12**	**-0.09**	**-0.08**	**-0.17**	**-0.10**	**-0.09**	**0.67**					
OBS9	**-0.08**	**-0.11**	-0.10	-0.02	**-0.11**	**-0.19**	**-0.11**	**-0.10**				
OBS10	**-0.19**	**-0.26**	**-0.09**	**-0.11**	**-0.22**	**-0.10**	0.01	0.009	**0.21**			
OBS11	**-0.18**	**-0.17**	**-0.08**	**-0.08**	**-0.17**	**-0.16**	**-0.23**	**0.009**	**0.07**	**0.10**		
OBS12	**-0.14**	**-0.12**	**-0.07**	**-0.09**	**-0.17**	**-0.11**	**-0.24**	**-0.17**	-0.02	**0.07**	**0.53**	
OBS13	**-0.10**	**-0.09**	-0.01	**0.14**	**-0.15**	**-0.08**	**-0.12**	**-0.10**	**-0.06**	-0.04	**0.11**	**0.14**

Note: Bold characters represent significant pairs based on the test of the significance of residuals.

TABLE 15

Correlations between generalized residuals (in deviations from the individual mean) for the communications sector

	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12
OBS2	**0.47**											
OBS3	**0.23**	**0.39**										
OBS4	-0.06	-0.05	0.06									
OBS5	0.08	-0.06	**-0.18**	0.31								
OBS6	0.02	0.00	-0.10	0.10	**0.44**							
OBS7	0.06	**0.14**	-0.07	-0.20	-0.06	0.01						
OBS8	-0.15	-0.12	-0.07	**-0.19**	-0.12	-0.10	**0.47**					
OBS9	0.01	-0.08	0.03	0.06	-0.15	**-0.26**	-0.07	-0.11				
OBS10	-0.09	-0.15	-0.09	-0.08	**-0.26**	**-0.22**	0.06	0.09	**0.31**			
OBS11	-0.06	0.00	0.08	-0.09	**-0.23**	**-0.21**	0.00	**-0.19**	**0.28**	0.09		
OBS12	-0.11	0.03	0.01	-0.03	**-0.17**	-0.13	0.05	-0.11	-0.07	0.01	**0.40**	
OBS13	**-0.20**	-0.05	0.06	0.02	-0.10	-0.07	-0.08	-0.08	-0.10	-0.07	0.02	0.01

Bold characters represent significant pairs.

TABLE 16

Correlations between generalized residuals (in deviations from the individual mean) for the financial services sector

	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12
OBS2	**0.44**											
OBS3	-0.06	**0.22**										
OBS4	-0.04	**0.26**	**0.23**									
OBS5	0.05	0.51	**0.07**	**0.67**								
OBS6	0.22	0.07	**-0.05**	0.25	**0.18**							
OBS7	0.30	0.08	0.17	0.02	0.09	**0.23**						
OBS8	0.09	0.11	-0.13	0.20	0.04	0.06	-0.26					
OBS9	0.31	**0.05**	**0.01**	-0.26	**-0.22**	**-0.01**	**0.07**	0.18				
OBS10	0.09	0.11	0.13	0.17	0.06	0.00	-0.14	**0.42**	0.39			
OBS11	-0.11	**-0.06**	**0.04**	-0.05	**-0.07**	**0.08**	**0.09**	0.11	**0.16**	-0.01		
OBS12	0.09	**0.00**	**-0.15**	-0.05	**0.06**	**0.02**	**0.18**	0.05	**0.17**	0.09	**0.40**	
OBS13	0.20	**0.43**	**0.10**	**0.16**	**0.32**	**0.19**	**0.12**	0.19	**0.10**	0.29	**0.08**	**0.25**

Bold characters represent non-significant pairs.

CONCLUSION

In their efforts to innovate, firms face a number of obstacles linked to feasibility and marketing risks, the high cost of innovation projects, issues of funding, the availability of factors needed to implement innovative projects, internal resistance to innovation and the regulatory environment. We used the data from the innovation survey conducted by Statistics Canada for the communications, financial and technical services sectors in order to examine the causal factors for the perception of obstacles as well as possible complementarities between them.

Our analysis based on different approaches (descriptive statistics, principal component analysis, econometric estimate) shows that the perception of impediments to innovation varies according to industrial affiliation, the size of firms, the perceived competitive environment and whether or not firms engage in R&D. There was more concern among large firms than smaller ones about risks of feasibility and success, high costs and uncertainty related to costs, and about internal obstacles to innovation. On the other hand, funding difficulties (equity capital, outside capital, sinking fund) and the lack of special equipment were perceived more strongly as obstacles to innovation by small firms. The shortage of qualified staff and the risk that the benefits of innovation might not be appropriated were not perceived differently by small and by large firms. With few exceptions, impediments to innovation were felt most strongly in the technical services sector. The communications sector was concerned less about technical and business risks and more about the regulatory environment. The financial services sector reported little concern for the lack of funds, and greater concern for the internal resistance to change. For all three groups of industries, the main impediment to innovation was the high cost of innovation projects. Competitive pressures heightened the perception of obstacles, especially those linked to technical and business risks, the loss of intellectual property and cost predictions. Firms that engaged in R&D perceived the major obstacles more strongly than those that did not.

The study pointed to mostly intra-group complementarities, the groups being those defined in the survey questionnaire. Otherwise, two types of inter-group complementarities were identified. Costs and risks seemed to go together, as did problems of internal and external governance. There was no evidence to conclude that high risks would lead to costs or vice versa, or that increased regulations would be accompanied by higher internal resistance to change. Our analysis simply suggested that these pairs of apparently independent obstacles form a single unit. Solving one of these obstacles will probably require a solution to its complementary obstacle. On the other hand, our findings also suggest that there is much less complementarity between problems linked to the shortage of qualified staff, risk management, funding for innovation, attitudes to change and institutional framework than is implied in the concept of innovation systems which assumes a set of region-specific or country-specific complementary characteristics.

With respect to questionnaire development, it would be interesting to determine to what extent the ordering of questions, the wording of questions (the use of the same terms, e.g. “risk” or “costs”) and the grouping of questions have an effect on the answers. It is in fact surprising to note that the sign and magnitude of correlations between obstacles are a function of their proximity in the questionnaire (the distance from the diagonal in the correlation matrix for pairs of obstacles). If certain questions are in fact answered in the same way no matter where they are in the questionnaire, it might be possible to eliminate some of them to simplify the questionnaire.

It would be interesting to compare the complementarities between barriers to innovation for other industries and other countries, and to test the hypothesis that some innovation issues might be common to all firms.

APPENDIX 1 - ECONOMETRIC MODEL

Each of the 13 barriers to innovation is modelled as a latent variable:

$$y_{ij}^{*}= \alpha_j + \beta_j' x_{ij} + u_{ij} \qquad i=1,\ldots,n_j \quad j=1,\ldots,13$$

where the observations are indexed using i and the impediments using j, and x_{ij} are the explanatory variables. The error terms of latent variable equations are assumed to be distributed identically and independently in accordance with a law of multivariate normal distribution of zero average and of contemporary variance-covariance matrix Σ:

$$E(u_{ij}u_{ik})=\sigma_{jk} \qquad \forall_i \text{ , } E(u_{.j})\sim N(0,\sigma_{jj} I_{nj}).$$

Answers related to obstacles are ordered, and fall into five categories. We thus have an ordered multinomial probit model. For each obstacle we observe the answers:

$$y_{ij} \in \text{ group 1, } (Z_{ij1}=1), \text{ if } -\infty \leq y^{*}_{ij} \leq \varphi_{1j}$$

$$y_{ij} \in \text{ group 2, } (Z_{ij2}=1), \text{ if } \varphi_{1j}< y^{*}_{ij} \leq \varphi_{2j}$$

$$y_{ij} \in \text{ group 3, } (Z_{ij3}=1), \text{ if } \varphi_{2j}< y^{*}_{ij} \leq \varphi_{3j}$$

$$y_{ij} \in \text{ group 4, } (Z_{ij4}=1), \text{ if } \varphi_{3j}< y^{*}_{ij} \leq \varphi_{4j}$$

$$y_{ij} \in \text{ group 5, } (Z_{ij5}=1), \text{ if } \varphi_{4j}< y^{*}_{ij} \leq \infty,$$

where Z_{ijl} (l=1,...5) are dichotomous variables.

The estimator of the maximum likelihood of parameters α_j, β_j and φ_{lj} (l=1,…,5) is:

$$\max \log L_j = \sum_i Z_{ij1}\log [\Phi(\alpha_{1j}-\beta_j' x_{ij})] + Z_{ij2}\log [\Phi(\alpha_{2j}-\beta_j'x_{ij})-\Phi(\alpha_{1j}-\beta_j'x_{ij})]$$

$$+ Z_{ij3}\log [\Phi(\alpha_{3j}-\beta_j'x_{ij})-\Phi(\alpha_{2j}-\beta_j'x_{ij})] + Z_{ij4}\log [\Phi(\alpha_{4j}-\beta_j'x_{ij})-\Phi(\alpha_{3j}-\beta_j'x_{ij})]$$

$$+ Z_{ij5}\log [1-\Phi(\alpha_{4j}-\beta_j'x_{ij})].$$

where Φ represents the normal cumulative distribution function and α_{lj} (l=1,…,5)=$\varphi_{lj}-\alpha_{j.}$ The category thresholds φ_{lj} are estimated simultaneously using the structural parameters of the model, but cannot be identified separately from parameters α_j.

Residuals of the latent dependent variable equations cannot be observed. Gouriéroux et al. (1987) defined the generalized residuals using the mean of the error term of the specification of the latent variable conditional on the value observed for the discrete variable $\hat{u}_{ij}(\theta_j)= E(u_{ij}|y_{ij})$. For the multinomial probit, we have:

$$E(u_{ij}|y_{ij})= Z_{1ij} [-\varphi(\alpha_{1j}-\beta_j'x_{ij})] / [\varphi(\alpha_{1j}-\beta_j'x_{ij})]$$

$$+ Z_{2ij}[\varphi(\alpha_{1j}-\beta_j'x_{ij})-\varphi(\alpha_{2j}-\beta_j'x_{ij})] / [\varphi(\alpha_{2j}-\beta_j'x_{ij})-\varphi(\alpha_{1j}-\beta_j'x_{ij})]$$

$$+ Z_{3ij}[\varphi(\alpha_{2j}-\beta_j'x_{ij})-\varphi(\alpha_{3j}-\beta_j'x_{ij})] / [\varphi(\alpha_{3j}-\beta_j'x_{ij})-\varphi(\alpha_{2j}-\beta_j'x_{ij})]$$

$$+ Z_{4ij}[\varphi(\alpha_{3j}-\beta_j'x_{ij})-\varphi(\alpha_{4j}-\beta_j'x_{ij})] / [\varphi(\alpha_{4j}-\beta_j'x_{ij})-\varphi(\alpha_{3j}-\beta_j'x_{ij})]$$

$$+ Z_{5ij} [\varphi(\alpha_{4j}-\beta_j'x_{ij})] / [1-\varphi(\alpha_{4j}-\beta_j'x_{ij})]$$

knowing for example that:

$$E(u_{ij}|\alpha_{1j}-\beta_j'x_{ij} \leq u_{ij} \leq \alpha_{2j}-\beta_j'x_{ij})$$

$$= -[\varphi(\alpha_{2j}-\beta_j'x_{ij})-\Phi(\alpha_{1j}-\beta_j'x_{ij})] / [\varphi(\alpha_{2j}-\beta_j'x_{ij})-\Phi(\alpha_{1j}-\beta_j'x_{ij})]$$

where φ is the density function of the normal distribution. In practice, generalized residuals are evaluated at the estimated value of parameters θ and are denoted by $\hat{u}_{ij}=(\hat{\theta})$.

The correlations between pairs of generalized residuals provide information about the sign and magnitude of correlations between the barriers to innovation conditional on explanatory variables (x_{ij}), i.e. maintaining the other variables constant. To determine whether covariances between generalized residuals are significantly different from zero, we use the score test (Gouriéroux et al. (1989)). Given the null hypothesis that $\sigma_{jk}=0$, the score statistic is:

$$\xi_{jk} = \left(\sum_{i=1}^{n} \hat{\hat{u}}^{0}_{ji} \hat{\hat{u}}^{0}_{ki} \right)^2 \Big/ \sum_{i=1}^{n} \left(\hat{\hat{u}}^{0}_{ji} \hat{\hat{u}}^{0}_{ki} \right)^2$$

where $\hat{u}_{ji}(\theta_j) = E_{\theta j}(u_{ji}/y_{ji})$

$$\hat{\hat{u}}^{0}_{ji} = \hat{u}_{ji}(\hat{\theta}^{0}_{j})$$

$$\hat{\theta}^{0}_{j} = (\alpha_{1j}, \alpha_{2j}, \alpha_{3j}, \alpha_{4j}, \beta_j)$$

Given H_0, the score statistic is distributed as a χ^2 having one degree of freedom.

APPENDIX 2 - OBSTACLES TO INNOVATION

Linked to risk

OBS1	High risk related to the feasibility of an innovation project.
OBS2	High risk related to successful marketing of the innovation.
OBS3	Innovation is easily copied by other firms.

Linked to costs

OBS4	Difficulty of predicting the costs of innovation.
OBS5	High costs of innovation projects.
OBS6	Long depreciation period for innovation.

Linked to the availability of inputs

OBS7	Lack of equity capital for the implementation of innovative projects.
OBS8	Lack of outside capital for innovation projects.
OBS9	Shortage of qualified staff for innovation projects.
OBS10	Lack of equipment for the implementation of innovation projects.

Linked to the type of firm

OBS11	Internal resistance to innovation.
OBS12	Prolonged administrative processing or authorization to implement innovation projects.

Linked to legal aspects

OBS13	Legislation and regulations having an impact on innovation projects.

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