Measuring Innovation Competencies and Performances
A Survey of Large Firms in Belgium

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Abstract

Based on original survey data, this paper provides evidence on firms' innovation competencies and performances in Belgium. The relationship with firm size and technological opportunity is systematically evaluated. The first conclusion is that firms recognize the strategic importance of innovation but fail to undertake the "practical" steps to develop it. Large firms globally better master innovation competencies. However, small firms allocate the largest share of profits to finance innovative projects. In terms of performances, small and large firms, as opposed to medium ones, show the best results for their R&D investments and patent applications. It is also shown that the share of turnover due to incremental innovation is the highest within small firms, while technological breakthroughs are more important within large firms. There is a positive relation between technological opportunity and innovation competencies, R&D investments and patent applications. Services firms have relatively weak records on all innovation indicators but perform well concerning human resources, educational activities and the management of market information. Foreign firms invest significantly less in R&D than local firms. Finally costs- and risks-related barriers to innovation are the most important to all firms, whatever the size and technological opportunity.

JEL: O31, O32, O34, L25

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1. Introduction

For more than 50 years, innovation has raised a growing interest among the academic, politic and business worlds. It is increasingly recognized as a key driver of long term firm's growth [Geroski (1995), Crépon et al. (1998), Roper and Love (2002)]. In order to innovate, firms need to master various competencies such as the ability to generate innovative ideas, to implement the most promising ones, and to develop a culture of innovation within the firm. The objective of this paper is to get a quantitative insight into these competencies, thanks to an original survey of Belgian firms and Belgian units of foreign groups. It will first describe the questionnaire and then evaluate the firms' innovation competencies and performances. The role of the firm size and technological opportunity is also analysed[1].

The paper is organized as follow. After reviewing past initiatives in terms of innovation surveys, section 2 describes the questionnaire. Section 3 summarizes the firms' scores on various innovation indicators (R&D, patents and percentage of sales due to innovation). The statistical results of the firms' competencies are provided in section 4. In section 5, fifteen potential barriers to innovation are evaluated. Section 6 concludes.

2. The Questionnaire – Mapping the innovation process

Since the early nineties, several innovation surveys have been implemented[2]. The general objective of these surveys is to better understand the firms' innovation activities: Who are the most innovative firms? What kind of innovations do they launch? Why do firms innovate? What is the impact on their performances? In 1992, the OECD published the Oslo Manual in an attempt to standardise the data collection methodology. It provides guidelines on how to conduct an innovation survey: the different innovation indicators, the issues to be tackled and the methodological considerations to take into account. Then in 1993, EUROSTAT together with the OECD launched a standardised questionnaire that was to be used in most EU countries (the Community Innovation Survey, CIS). It surveyed the types of innovation activities the firm was engaged in, the objectives pursued, the information sources used, the cooperation agreements and hampering factors. For the first time, internationally comparable and comparative studies were possible. A second CIS was launched in 1997, followed by a third one in 2002. The Community Innovation Survey raised an important interest among EU researchers[3]. Other surveys have been developed in Japan, Canada and in the US[4]. In the late nineties another

[1] The technological opportunity of the sector was determined thanks to the OECD classification into four categories: HT= aeronautic construction, desks and computing machines, pharmaceuticals products, radio, TV and telecommunication machines ; MH= professional equipment, motorcar vehicles, electric machines, chemical industries, other transport equipment, non-electric machines ; ML= rubber and plastic materials, naval construction, other industrial sectors, non-iron metals, non-metallic mineral products, metallic works, petroleum and coal, steel industry ; LT= paper, printing and editing, textile industry, clothing and leather, food, drinks and tobacco, wood and furniture. We added a category for all service firms: commerce, hotels et restaurants, transports, posts et telecommunications, insurances, financial services, real estate activities, computer activities.

[2] A review of past initiatives in terms of innovation surveys is provided by Archibugi and Pianta (1996).

[3] See among others Veugelers and Cassiman (1999), Duguet and Monjon (2001) and Lööf and Heshmati (2002).

[4] See among others Nagata *et al.* (1994), Baldwin and Johnson (1996) and Cohen *et al.* (2002).

legitimate objective rose: the identification and measurement of the competencies that come into play in the firms' innovation process. A methodology to achieve this was proposed by François et al. (1999). This led to a vast survey realised by the SESSI (Industrial Statistics Service at the French Ministry of Industry).

In line with the SESSI survey, in 2000 the Solvay Business School launched a questionnaire that was sent to the largest firms in Belgium in each industry. In comparison to other innovation questionnaires, six main differences are worth to notice. First it adopts a systematic approach of the competencies along the entire innovation process, from ideas generation to commercialisation of the new product or process. Second, firms have to give a relatively precise evaluation of their competencies since most questions have to be answered on a Likert scale ranging from 0 to 5 and not on a "yes or no" basis. Third, all firms have to answer all questions and not only the companies that have introduced an innovation over the last few years preceding the survey. This reduces the risk of bias towards innovative firms. Fourth, the survey was not restricted to manufacturing firms. Services firms also answered the questionnaire. Fifth, all competencies were assessed thanks to a large range of questions. This enabled the collection of detailed information but led to a relatively low response rate, mainly because of the length of the questionnaire. Finally, this is the first Belgian survey dedicated to the firms' innovation competencies.

In order to build the questionnaire, the first step was to get a good understanding of the innovation process and its environment. Figure 1 summarizes them.

[Insert Figure 1 around here]

The box in dotted line represents the firm. Inside the box are the four innovation competencies assessed in the survey: the ability to develop a culture of innovation, the capacity to generate ideas, the capacity to implement ideas, and the efficient management of intellectual property. The firm's innovation competencies and performances are influenced by the external stock of knowledge (left of the box), the barriers to innovation (right of the box) and regulation aspects. Except the regulation issue all other issues are tackled in specific parts of the questionnaire.

The firm's culture surrounds all aspects of the innovation process so that the development of a culture of innovation becomes a competence in itself. Depending on the firm's culture, people will be more or less inclined to look for innovative ideas and try to develop them towards commercialization. Similarly, the firm's culture will influence the willingness to transform the firm's organization in a way that is convenient for innovation. Two sets of questions refer to this competence. The first set deals with the mechanisms firms put in place to develop a culture of innovation. The second one determines the importance assigned to various innovation areas: improvement of existing products, services and processes, development of radical innovations, improvement of the firm's organization, improvement of the information management systems, and training.

The innovation development process begins with the generation of ideas. In order to generate ideas firms can develop an internal research capacity, form collaborative research agreements, and/or use various external and internal information sources. Internal research can be divided into three main activities: basic research, applied research and development activities[5]. The questionnaire asks firms the percentage of their R&D budget that is allocated to these three activities, in addition to the total share of sales allocated to R&D. This repartition of the R&D budget is important to know since the

[5] *Basic research* is experimental or theoretical work undertaken primarily to acquire new knowledge without any particular application or use in view. *Applied research* is also original investigation undertaken in order to acquire new knowledge, but it is directed primarily towards a specific practical aim or objective. *Experimental development* is systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (Frascati Manual, 1993).

more resources are allocated to basic and applied research, the more breakthrough innovations might emerge. Development activities lead to more incremental innovations. Firms can also develop their research capacity in collaboration with other firms or institutions (Tether, 2002). This is traditionally recognized to have a positive effect on the firms' performances (Ritter and Gemünden, 2002), and to be complementary to the firms' technological competencies (Tyler, 2001). The questionnaire investigates whether firms have been actively involved in joint R&D projects for the past three years. Various possible partnerships are proposed: with competitors, vertical partners, universities, consultants, complementary firms and other firms of the same group. These institutions form an external stock of knowledge that might be used by firms. In addition to the generation of ideas, the firm's own research activities help to improve its absorptive capabilities of own and external R&D (Cohen and Levinthal, 1990). Various other ways to generate innovative ideas internally are assessed: the recruitment of people that are likely to bring new skills to the firm, the organization of team work and brain storming sessions, and the use of competitive intelligence processes. Finally firms use external information from the patents databases, scientific literature, and from benchmarking practices and market surveys.

The next step is the implementation of some of the innovative ideas previously generated. Four aspects of this competence are studied in the questionnaire: the storage and selection of ideas, the development of the technology, the innovation marketing, and the financing capacity. Indeed, only a small share of the pool of ideas that have been generated will receive the necessary resources to enter the development step. And much fewer will go until large scale production and commercialization. Therefore, firms need to have an efficient ideas selection process enabling them to track down the projects to push forward [Montoya-Weiss (2000), Cooper et al. (2001), Nemati et al. (2002), and Tidd and Bodley (2002)]. After an innovative project has been selected, the required technology can be developed internally, bought externally (licenses, trademarks, rights to use patented inventions…) or acquired by R&D projects subcontracting [Veugelers (1997) and Veugelers and Cassiman (1999)]. Finally firms can buy or create high-tech start-ups, or acquire another firm's business unit essentially for its technological competencies. Surveyed firms are questioned about their use of these knowledge acquisition mechanisms. Managing the relationship between the technology department, the marketing department and the customers is a third important element in the implementation of innovative ideas [Bonnet (1986), Gupta and Wilemon (1988 and 1990), Griffin and Hauser (1996), and Olson et al. (2001)]. A lack of communication between the marketing department and customers might lead to poor results. Indeed, if firms want to profit from their technological breakthroughs, they have to make sure they develop products that customers want. Furthermore, a good communication between marketers and scientists is crucial if firms want to avoid marketers to conceive new products that perfectly answer the customers' needs but are technologically infeasible. The financing capacity of the firm is the last important aspect concerning the ability to implement ideas (Adam and Farber, 1994). A firm can finance an innovative project internally by allocating a share of its profits to it. It can also use external funding sources, from the private (bank loans) or public (subventions) sectors. Less traditional financing means are assessed in the survey too, i.e. the recourse to venture capital funds and to the management buy-out system.

At the end of the process comes the commercialization of the innovation. A set of questions enable the evaluation of the firms' innovation output by the percentage of turnover due to either radically new or improved products and/or processes.

The capacity of the firm to protect its intellectual property is important all over the innovation process. If the firm does not succeed in protecting its intellectual capital, it might not be able to appropriate the rents necessary to compensate for the costs of development it has supported. Firms have thus to develop an active intellectual property strategy that must be linked with their technology and business strategies (Granstrand, 2001). Beside some general questions about the firms' patenting performances, most questions regard their ability to effectively protect their inventions, to manage their patents portfolio, and to assess the barriers to systematic patenting of their significant inventions.

The last part of the questionnaire is dedicated to 15 potential barriers to innovation. Some barriers relate to the costs and risks of innovation, others to internal and external rigidities, to the lack of competencies, and to regulation aspects.

The questionnaire was sent to the CEO's of 1301 large firms active in all sectors in Belgium. A total of 148 questionnaires were filed and sent back. This represents a response rate of 11%, significantly higher for large firms (22%)[6].

[Insert table 1 around here]

Large firms account for 33% of the sample, and medium-sized and small firms for 36% and 31% respectively (see table 1). Services firms is the most represented category with 28% of the sample, followed by MH firms that account for 26%. HT firms account only for about 10% of the surveyed firms. Finally, 52% of firms are Belgian subsidiaries of foreign groups, which is quite characteristic of the Belgian economy.

3. Innovation Performances

Three types of innovation indicators are analysed in the survey. First the share of sales allocated to R&D, an indicator of input into the innovation process. Second the firms' patent applications. Lastly an output indicator, i.e. the share of sales due to innovative products or processes. Figure 2 shows that on average, firms allocate 3.3% of their sales to basic and applied research. The percentage is the highest for large and small firms, as opposed to medium firms[7]. This U-shaped curve probably stands for the fact that firms, in order to grow from small to large scale, need resources that could otherwise be used for research. Medium firms would be in a kind of intermediate step where costs reductions, efficiency improvements and organisational adaptations are the priorities in order to move towards large scale production. This observation goes against the Schumpeterian hypothesis that large firms are the most R&D intensive. More precisely, the present results agree with Schumpeter concerning the investments in basic and applied research, but not when looking at the investments in development activities. This decomposition of R&D into research activities on the one side and development activities on the other side might give a new insight into the wide debate on the relationship between firm size and R&D activities. Actually this could be one explanation of the divergence of opinions among followers and challengers of the Schumpeterian hypothesis [Acs and Audretsch (1991), Cohen et al. (1996), Crépon et al. (1996)]. Development activities account for an average of 4.3 % of firms' sales in Belgium. The highest percentage is found for small firms (6.9 %). Firms in high technological opportunity sectors are more active in both basic and applied research and in development activities. The same applies to local firms with respect to Belgian units of foreign groups[8]. Indeed, responding firms that belong to a foreign group often claim to be only production or distribution centers of products that have been conceived outside Belgium. They have relatively little decision power for innovation investments, and more particularly for research activities.

[Insert figure 2 around here]

A complementary indicator relates to the number of patent applications. Table 2 shows that only one firm has applied for more than 100 patents in 2000, while most firms have not applied for any patent at all, or only a small number. This highly skewed distribution shows that patents data are not an indicator of innovative effort and reflects partly the technological performances of firms.

[6] Small firms have less than 200 employees, medium firms have between 200 and 499 employees, and large ones over 500.

[7] This is in line with the U-shaped relationship between size and research intensity found by Bound et al. (1984).

[8] The categorization according to the firm nationality is presented only for the research indicator since it is the only clear and relevant result for this aspect.

[Insert table 2 around here]

The percentage of firms with at least one patent application over the last 10 years is presented in figure 5. This concerns 53% of the respondents. As for the R&D intensity, there is an U-shaped relationship with the size of the firm, and a positive relationship with the technological opportunity of the sector of activity. More than 70% of HT and MH firms have filed at least 1 patent application over the last 10 years. At the opposite, only one out of five firms in the services sector has applied for a patent.

[Insert figure 3 around here]

The percentage of the firms' patents portfolio that is exploited in their own production is 64%, while only 8.4% is licensed to other institutions (see figure 4). Large firms have a higher propensity to license some of their patents. At the opposite, when a smaller firms exploit a patent this is mainly through its own production. HT and MH firms have the smallest propensity to license their patents and services firms the largest.

[Insert figure 4 around here]

The last indicator of innovation performance concerns the share of new products, processes and services in the firm's turnover. It can be split into improvement activities and radical innovation (see figure 5).

[Insert figure 5 around here]

Except for services firms, it seems that the commercialisation of innovative products is equally important to all firms. Only the magnitude of radical innovation versus improvement enables to distinguish between firms of various sizes and technological opportunity classes. Large firms have a relatively high percentage of turnover due to radical innovations, while small firms favour the improvement of existing products. The same applies to HT and MH firms with respect to ML and LT firms.

4. Innovation Competencies

The differences observed among firms in terms of innovation performances might be due to different competencies. In this section we measure the extent to which firms master four major competencies that could help them to perform on the various innovation indicators studied here above. These competencies are the development of a culture of innovation, the generation of innovative ideas, the implementation of ideas, and the management of intellectual property. The following figures give global averages across the whole sample. The differentiation according to the firms' size and technological opportunity is provided in table A1 in appendix.

4.1. The Development of a Culture of Innovation

Competencies relative to the development of a culture of innovation are presented in figure 6. The three best scored competencies are the development of explicit corporate values that encourage innovation and learning, the openness to innovative management solutions, and the explicit introduction of innovation in the firm's global strategy. It is worth noticing that these "strategic" aspects call for less resources and are less action-oriented than the three less quoted competencies. These are the use of a knowledge management process, the explicit recognition and reward of people for improvement of knowledge or innovation, and the development of a specific training program for highly-skilled professionals. In other words firms generally underline the importance of developing a culture of innovation but do not necessarily allocate the required resources to sustain this objective.

[Insert figure 6 around here]

Large firms traditionally better master these competencies (see table A1 in appendix). Nevertheless, there are three interesting exceptions. First, small firms promote internal entrepreneurship the most. Second, large firms' organization is more often recognized as rigid, as opposed to flexible. Finally, they are less prompt to reward their employees for innovation and improved knowledge. There is thus an antagonism between large firms that try to develop a culture of innovation but that are more rigid, and small firms that are less able to develop a culture of innovation but promote intrapreneurship the most. Concerning the technological opportunity effect, HT and MH firms score the highest for all questions, except for the time allocated to external training and education. Services firms clearly pay the most attention to training.

Concerning the importance firms give to various innovation areas, figure 7 first shows that products innovations are favoured in comparison to processes and services innovations. Going a little further, we notice that improvement activities are more targeted than the launch of radical innovations. Firms tend thus to favor short term amelioration perspectives as opposed to longer term renewal perspectives, be it for their products, processes or services.

[Insert figure 7 around here]

Three main areas are less important to small firms: the training of the workforce, the improvement of information systems, and the improvement of the organizational structure. This larger focus towards production aspects, as opposed to organizational issues is due to the more flexible and informal structure of small firms. Services firms give a high importance to the training of the workforce. They also pay much attention to the management of information systems and to the development of new services.

4.2. Generation of Innovative Ideas

The second competence assessed in the survey is the ability to generate innovative ideas through either internal or external mechanisms.

- ***Internal measures to generate ideas***

Figure 8 shows that team work and brain storming sessions are by far the most widely used measures. At the opposite, firms rarely recruit executives from outside their main business sector. This could be due to too specific and complex activities or because they do not value the opportunity of a diversified and multicultural environment. Moreover only one firm out of four use patent literature and competitive intelligence processes.

[Insert figure 8 around here]

Table A1 in appendix reveals that large firms pay much more attention to almost all internal measures assessed in the survey. Concerning the technological opportunity effect, three results have to be noticed. First, the work organization of ML and LT firms stress team working and brain storming sessions less than other firms. Second, services firms show a significant above the average score for the access to new skills through their recruitment process. Finally, the patent literature and competitive intelligence processes, even if not often used, are a more important source of ideas for HT firms.

- ***External information sources***

Beside the internal generation of ideas, firms can look outside their boundaries. Figure 9 presents a ranking of various external information sources firms use as an input in their innovative process.

[Insert figure 9 around here]

Customers are by far the most important source of information with 77% of firms evaluating this source as very important. At the opposite, only 7% of firms consider consultants information as an

important input in their ideas generation process. 44% of firms give a high importance to their competitors' information. Then come the other firms belonging to the group and the suppliers. Only 12% of firms value the information generated by universities. In general, small firms rely less on external information than large and medium ones[9]. HT and MH firms use universities and research institutes as information source twice more often than low-tech firms. This is in line with their important involvement in basic and applied research, for which knowledge-generating institutions play a crucial role. ML and LT firms use information from their commercially related partners the most (customers, competitors and suppliers), while services firms distinguish themselves by the importance they give to other firms in the same group. One reason is that many Belgian services firms belong to a large, often international, group. Since the knowledge they need is quite specific to their type of activity it is convenient for them to share information within the group. They also use consultants' information twice more in comparison to the global average.

- ***Collaborative research agreements***

Collaborative research is an additional way to further develop the knowledge base of a firm and improve its absorptive capacity. In the sample, 87% of firms claim to have actively participated in at least one joint R&D project for the past three years. This is illustrated in figure 10. The percentage of firms involved in collaborative research agreements is the highest for large firms. Services firms score significantly under the average.

[Insert figure 10 around here]

Figure 11 shows that 68 % of firms participated in joint R&D projects with vertical partners (customers and suppliers) for the past three years, which is the highest percentage. At the opposite, the less common type of collaboration is joint research with competitors. Collaboration with other firms within the group is also quite common and consultants are again poorly rated. Approximately 56 % of firms collaborate with universities, which is mostly due to large firms in higher technological opportunity sectors[10].

[Insert figure 11 around here]

A comparison between these results and the information sources firms use reveals that customers are the most important external source of innovative ideas. At the opposite, competitors, that were an important source of information, are very poorly rated as partner for collaborative research agreements. Finally, consultants get a very bad score, be it as information source or as research partners.

4.3. Implementation of Innovative Ideas

The ability of firms to take advantage of their innovative ideas is assessed from four viewpoints: the ability to store ideas and choose the most promising projects, the sourcing of the technology required by the innovation projects, the capacity of firms to efficiently manage the link between the technology department, the marketing department and their customers, and the capacity to finance innovation.

- ***Organisational Issues***

The advantages for innovation of an organization based on projects and multidisciplinary teams as opposed to an organization based on hierarchical functions are well understood by firms (see figure 12). HT and MH firms appear to be much more reliant on a project organisation (85%) than other firms (only 58%), while the firm's size is not much correlated with the type of organization.

[Insert figure 12 around here]

[9] See synthetic table A1 in appendix.

[10] A similar result is found by Bayona Sàez et al. (2002) on a sample of Spanish firms.

Only 32% of firms seem to foster staff rotation. The importance of this practice does not vary according to the technological opportunity but is almost twice higher in large firms.

- ***Ideas storage and selection:***

It is not worth generating innovative ideas if the firm does not store them systematically and if it does not have an efficient ideas selection process. Figure 13 highlights a low global score for this competence, especially concerning the systematic storage of innovative ideas that could potentially be exploited later.

[Insert figure 13 around here]

Large firms score the best, like HT and MH firms (see table A1 in appendix). Due to their smaller size, the knowledge organization of small and medium firms is more informal. Their ideas codification, storage and selection process is thus much less systematic than within large firms.

- ***Technology development:***

The implementation of innovative ideas often requires the mastering of several complementary technologies. Firms can develop them internally through their own R&D activities, or acquire external technology to use in their own innovations. This last opportunity has been increasingly used since 1995 [Edler et al. (2002)]. A firm relies on external sources when it does not possess the relevant competence internally, when the development costs are too high, or when the technology is protected by intellectual property rights. Figure 14 shows that about 38% of firms buy external technology (licenses, trademarks, know-how…) and/or subcontract research projects. This percentage is higher for large firms, maybe because they are the only ones to have enough resources to do so. In small firms, innovation projects would thus be started only if they possess the capacity to develop the technology internally. This would be one explanation of their high score for the percentage of sales allocated to development activities, in comparison to their weak score concerning external knowledge acquisition. HT firms buy external technology less often than other firms. Due to the high complexity of the technology they use, it is probably better for them to control the whole innovation process.

[Insert figure 14 around here]

Firms can also subcontract some research projects. Here again large, HT and MH firms show the best results (see table A1 in appendix). Services firms almost never subcontract research projects.

- ***Innovation marketing:***

The competencies relative to the marketing of innovations are globally well mastered by firms (see figure 15). They are the systematic monitoring of the customers' satisfaction, the development of specific marketing activities for the market introduction of innovations, and information exchanges between the marketing and technology departments. Large firms score the best for all aspects. Medium firms seem to face some problems with the exchanges between the marketing and technology departments. This is in line with the previous results where medium firms were found less innovative, probably because of organizational problems when growing from small to large scale production. Small firms score under the average for the development of specific marketing activities for their innovations and for the systematic monitoring of the customers' satisfaction. However, they score high concerning the exchanges between the marketing and technology departments.

[Insert figure 15 around here]

Services firms perform very well regarding the monitoring of the customers satisfaction and the development of specific marketing activities for their innovations. At the opposite they score under the average concerning the exchanges between the marketing and technology departments, where HT and MH firms show very good results. The technology department is actually more important for these firms than for services firms.

- ***Innovation financing :***

The scores of firms for the various innovation financing sources are very low. How to finance highly risky projects is indeed a key issue for most firms willing to innovate. Looking globally, figure 16 shows that internal funding sources are the most used, even if only 26% of firms consider this source of funding as very important. Small firms score slightly higher (37%). Public external sources for research are sometimes used by large and small firms but almost never by medium firms. Private funds are extremely rarely used. This is not surprising since the high risk inherent to most research projects tends to discourage banks to lend money to firms, due to the lack of collateral. These low results concerning the financing of innovation confirm the previous finding that firms understand the importance of innovation but fail to allocate many resources to it.

[Insert figure 16 around here]

HT and MH firms allocate a large share of their profits to innovative projects, in comparison to other firms. They also use public external funding sources more.

Venture capital funds are another way of finding resources to finance innovation. The firm can collaborate with external venture capital funds or develop its own internal venture capital fund. Nevertheless, this opportunity is almost never used: 10% of firms have an internal VC fund or collaborate with other VC funds. The management buy-out system is used by only 13 % of firms (see figure 17).[11]

[Insert figure 17 around here]

These financing techniques are mainly used by large firms and firms active in high technological opportunity sectors of activity.

4.4. Intellectual Property Management

Another key element in the innovation process is the firms' ability to efficiently manage their intellectual property rights[12]. Indeed, if a firm is not able to protect its intellectual property it will be unable to appropriate the innovation rents that are necessary to compensate for the past innovation costs. Various questions contribute to the evaluation of this competence (see figure 18).

[Insert figure 18 around here]

Less than 50% of firms claim to have an active IPR strategy. This shows that 50% of firms are either not interested in protecting their knowledge or that they favour less formal mechanisms, like secrecy or market lead, as opposed to property rights. The percentage of firms with an active IPR strategy can seem surprisingly low since the importance of the issue is largely recognized in the literature (Rivette and Kline, 2000). In general it appears from table A1 in appendix that large, and HT and MH firms feel more concerned with IPR than smaller, and LT and ML firms. Services firms score the lowest for all questions and the difference is particularly striking regarding the protection through patent applications: the existence of a centralised patent department that coordinates the company's whole patents portfolio, the use of an evaluation process for the patenting of the firm's inventions and the scrutiny of the competitors' patent applications.

The low percentage of firms that systematically integrate the risk of imitation is quite surprising. The percentage of ML and LT firms is particularly low. They seem to consider imitation to be "part of the game" and that trying to avoid it would be too costly in comparison to the potential gains. Most firms

[11] These results are similar to Freel's study (1999) about the financing of innovation within the UK.

[12] By intellectual property rights we mean patents, copyrights and trademarks.

do not scrutinize the competitors' patent applications either. Large firms are in fact almost the only ones to be interested in technology-related business intelligence.

Patents are an important protection mechanism regarding technological innovation. However, not all firms have the same propensity to patent. One reason for this can be a difference in the barriers to patent applications (see figure 19). The highest rated barriers relate to the lack of efficiency of the patent system. First, many firms consider market lead more efficient than patent protection. Second, more than 50% of firms feel unable to prevent competitors from copying their technology, even if it is protected by a patent. Third, many firms consider secrecy more efficient[13]. A second category of barriers relate to the cost of patents: the cost of protection in case of litigation and the cost of fees. Lastly, only 1 firm out of 5 do not patent because they lack of information on the system.

[Insert figure 19 around here]

Almost all barriers to patenting seem important to medium firms. This could partly explain that these firms have the lowest probability to have filed at least one patent application in the last 10 years. Small firms rate the cost-related barriers above the global average. Finally, large firms globally feel less constrained by the various potential barriers. HT and MH firms also tend to face less barriers than the average, except for the costs issues. ML and LT firms highlight globally more constraints, especially concerning the lack of efficiency of the patent protection. Even if the propensity to patent of services firms is lower, they do not face more barriers than the others. Actually they seem to face less barriers. Their main withholding with respect to patents is that they find market lead a more efficient protection mechanism and that they lack of information about the patenting process.

5. The Barriers to Innovation

Potential barriers do not only act against patent applications. Obstacles can come up at any time during the innovation process. They come from various sources, internal or external to the firm. In order to maximise the probability of success of an innovation project it might be worthwhile to assess the potential barriers beforehand. This way it is easier for the firm to anticipate problems and react proactively. Figure 20 shows that almost 60% of the responding firms assess the potential barriers to innovation beforehand. The percentage is higher for HT and MH firms and lower for services firms. There are very few differences according to the firm size.

[Insert figure 20 around here]

Costs- and risks-related issues are by far the most important barriers to innovation whatever the size and technological opportunity of the firm (about 60%). The second type of obstacles comes from the lack of flexibility and the lack of qualified personnel. In third position come some external factors related to the customers' rigidities and lack of reaction, and to the regulations. Fourth, there are the internal organisational aspects (poor communication, lack of leadership and internal rigidities). Finally other external factors like trade unions, lack of access to competent suppliers and imperfect protection system are perceived as barriers by less than 10% of firms.

Except for the costs- and risks-related barriers, the responses differ to some extent across firms categories. Internal organisational rigidities are rated the highest by large firms. The size of these firms can indeed induce less flexibility and less responsiveness to innovative projects. Medium firms face more external barriers related to the customers' behaviour and to the political environment: customers' organisational rigidities and lack of reaction, inappropriate public regulations and trade unions. Finally most obstacles faced by small firms come from a lack of resources: financial resources, qualified personnel, competencies and leadership. HT and MH firms seem to face relatively less obstacles to

[13] This is in line with Arundel's finding concerning the relative effectiveness of patents and secrecy for appropriation (Arundel, 2001).

their innovative projects. ML and LT firms face more internal barriers than the others (resistance to change and organisational rigidities). Services firms face more external barriers, like medium firms. Another important aspect for them is the lack of qualified personnel and competencies. This confirms the previous result that human resources are one of the most crucial issues for services firms.

6. Concluding Remarks

The objective of this study was to use an original survey to evaluate the firms' innovation competencies and performances in Belgium. A first general conclusion is that firms understand the strategic value of innovation but resist to concretely invest the necessary resources (financial, human and material) to sustain an effective culture of innovation. We also observe that on average, the most competent firms for innovation are large firms active in high technological opportunity sectors (HT and MH). They better introduce formal measures for the development of a culture of innovation. However, large firms are globally more rigid and less prompt to reward people for innovation than medium and small ones. Their ideas generation process uses the most patent literature and competitive intelligence processes. They globally do not use external information more than other firms, except information from universities and research institutes. They have the highest probability to be involved in collaborative research agreements, especially with universities, research institutes and public labs. They use more formal and systematic measures to store and select innovative ideas. Large, and HT and MH firms better manage the exchanges of information between the marketing and technology departments too. Even if public funds are not an important source of financing they use this opportunity more than others. Finally, they are by far the most competent concerning IPR management and claim to face less barriers to patents applications than medium and small firms.

Regarding innovation performances, large firms show good records on research and patent indicators. Nevertheless the relationship with firm size is rather U-shaped than linear. Indeed, medium firms recognize the importance of innovation and innovation-related areas but do not succeed in translating this into concrete R&D investments and patent applications. Moreover, medium firms get weak results concerning the participation to collaborative research agreements, the exchanges between the marketing and technology departments, the use of public funds, and the competence of IP protection. In terms of R&D investments, it is also noticeable that local firms perform better than foreign firms, which probably rely more on research performed elsewhere. Concerning the innovation output indicators, some interesting differences are found when looking at the type of innovation developed by firms. Large, HT and MH firms have a higher percentage of turnover due to radical innovation while smaller, ML and LT firms develop proportionately more incremental innovations. Only services firms have weak performances on both indicators.

The last issue tackled in the study was the potential barriers to innovation. The high costs, high risks and time constraints are the most important barriers for all firms. The other barriers are quite specific to the various categories. Large firms face internal organisational rigidities. Medium firms face external barriers due to regulations and customers' rigidities and lack of reaction to new products. They also suffer from the resistance to change on the part of their employees. Small firms lack internal resources: financial, human and managerial. ML and LT firms' innovative efforts are hindered by internal rigidities and resistance to change. Finally the crucial points for services firms are human resources, customers and regulations.

Some policy implications emerge from the above analysis. First, innovation is not only a matter of R&D. Services firms for instance show weak results on R&D and patent indicators, but score high for the human resources aspects, the management of information systems and the relationship with the market. In order to increase its innovation performances each country should thus adapt its S&T policies to the industrial structure of its economy, rather than implementing uniform measures for all firms. A second important policy implication results from the antagonism between small firms that stress incremental R&D the most, and the basic and applied research capabilities that are mainly concentrated among large firms. In a long term perspective it is thus important for the state to keep on

sustaining large firms innovative efforts. Third, financing innovation projects seems to be a tricky issue for most firms and the share of public funds appears very limited in this respect. It might therefore be useful for the state to adapt its action in order to guarantee a better access to innovation funding sources. It could for example review the system of public support granting and encourage the development of venture capital funds. Fourth, the lack of efficiency of the patent system is apparently the main reason why firms do not use the patent system systematically. In addition to the attempt of lowering the cost of patents, the state should thus also work on their efficiency in order to increase the firms' confidence in the patent system. Finally, the most important barrier to innovation that comes right after the financing and risks issues is the employees resistance to change and the lack of qualified personnel. This calls for the development and improvement of continuous education and lifelong learning programs, for which the state has a role to play through the national education system.

Appendix

Table A1: Innovation Competencies - Averages per type of firm

% of firms answering 4 or 5 on the 0 to 5 scale or YES to a yes or no question	Question type	Total	Large	Medium	Small	HT + MH	ML + LT	SERV
Culture								
Explicit corporate values encouraging innovation	scale	77.7	83.7	77.4	75.0	80.4	79.2	76.2
Openess to innovative management solutions	scale	73.0	77.6	66.0	76.1	80.8	64.8	73.8
Innovation explicitely introduced in global strategy	scale	68.7	85.4	54.9	71.1	80.4	66.0	62.5
Promotion of intrapreneurship to develop ideas	scale	66.9	65.3	59.6	78.3	76.9	64.8	58.5
Culture innovative rather than rigid	scale	63.7	59.2	68.6	65.9	74.5	56.6	62.5
Allocation of time for external training and education	scale	51.0	61.2	47.2	46.5	54.0	39.6	64.3
Innovation strategic goals communicated to employees	scale	44.2	54.2	38.0	43.5	61.5	32.7	40.0
Use of a knowledge management process	scale	42.2	50.0	40.0	41.9	54.0	37.7	39.5
Explicit rewards for innovation and improved knowledge	scale	40.5	34.7	46.0	44.4	45.1	38.5	41.5
Training program for highly skilled professionals	scale	34.5	44.9	28.3	31.1	36.5	37.7	28.6
Improvement of existing products and services	scale	88.8	87.8	96.0	90.0	91.8	88.2	94.9
Improvement of existing processes	scale	83.3	83.7	90.2	80.5	81.6	88.7	84.6
Training / education of the workforce	scale	74.8	77.6	80.4	65.1	68.0	65.4	95.1
New products development	scale	68.3	75.0	69.8	73.8	77.6	71.4	68.6
Management of information systems improvement	scale	67.8	73.5	74.5	53.5	58.0	69.2	78.0
Improvement of the organisational structure	scale	64.6	67.3	72.5	53.5	58.0	75.5	60.0
New processes development	scale	61.0	63.3	60.4	61.9	66.0	57.7	62.2
New services development	scale	47.2	54.2	50.0	40.0	45.8	35.8	69.2
Ideas Generation								
Internal measures								
Team work to generate new ideas	scale	73.5	77.6	71.2	71.7	82.7	63.0	75.6
Brain storming to generate new ideas	scale	66.2	80.9	60.8	58.1	69.4	58.8	73.2
New skills through the recruitment process	scale	44.9	53.2	42.3	42.2	49.0	35.8	55.0
Use of market surveys and benchmarking practices	scale	42.6	63.3	40.4	26.2	44.9	39.6	48.8
Use of patent literature as source of information	scale	26.4	47.8	25.6	13.6	38.8	28.6	17.1
Use of competitive intelligence processes	scale	24.5	36.7	20.4	19.0	30.0	25.0	21.1
Recruitment of executives from other sectors	scale	24.3	36.7	18.9	19.0	22.0	30.2	22.0
External information								
Customers information	scale	77.0	87.5	75.5	72.7	80.0	85.2	75.6
Competitors information	scale	43.9	45.8	50.0	37.0	44.2	50.9	36.6
Other firms in the group information	scale	32.9	39.6	43.8	24.2	32.6	29.2	52.6
Suppliers information	scale	27.2	26.5	28.8	27.3	27.5	32.1	22.0
Universities and research institutes information	scale	12.2	14.3	10.0	13.6	17.3	7.8	12.5
Consultants information	scale	7.4	10.4	8.0	4.4	7.8	1.9	15.0
Research collaboration								
Customers and Suppliers	yes/no	68.3	77.1	59.6	68.9	80.8	77.8	38.5
Firms in same group	yes/no	60.4	81.3	51.9	47.7	60.8	66.7	51.3
Universities	yes/no	55.9	83.3	38.5	46.7	73.1	55.6	33.3
Research institutes & Public labs	yes/no	49.0	72.9	34.6	40.0	69.2	50.0	20.5
Complementary firms	yes/no	41.7	46.7	34.6	45.2	53.9	44.0	21.6
Consultants	yes/no	33.1	43.8	25.0	31.1	36.5	24.1	41.0
Competitors	yes/no	16.6	29.2	9.6	11.1	21.2	18.5	7.7
Ideas Implementation								
Organisational issues								
Staff rotation fostering	scale	31.8	44.9	24.5	26.1	36.5	31.5	26.2
Rather projects organisation that hierarchical	scale	67.6	71.4	58.5	73.9	84.6	57.4	59.5
Ideas storage and selection								
IT-based Intranet for the codification of knowledge	scale	46.6	60.4	45.1	38.6	56.0	39.2	50.0
Formal project probability of success estimation	scale	43.2	60.4	36.0	39.5	64.7	36.0	32.5
Systematic storage of innovative ideas	scale	26.5	36.7	24.5	19.6	32.7	21.6	24.4
Technology development								
External technology buy	yes/no	38.6	58.3	26.9	31.1	28.6	52.6	36.7
Research projects subcontracting	yes/no	37.9	47.9	37.7	27.3	50.0	43.4	15.0

% of firms answering 4 or 5 on the 0 to 5 scale or YES to a yes or no question (continued)	Question type	Total	Large	Medium	Small	HT + MH	ML + LT	SERV
Marketing								
Systematic monitoring of the customers satisfaction	scale	68.0	79.6	64.2	62.8	68.0	63.0	78.0
Exchanges between marketing and technology departme	scale	67.1	85.1	37.8	74.4	85.7	66.7	64.7
Specific marketing activities for innovations	scale	62.0	78.3	64.0	51.3	66.0	61.2	69.4
Finance								
Important part of profits to finance innovative projects	scale	26.4	25.0	23.4	36.6	40.0	14.0	30.6
Use of public external funding sources	scale	14.0	23.3	6.8	17.9	23.5	17.8	0.0
Use of private external funding sources	scale	2.8	0.0	7.0	2.6	0.0	4.7	7.1
Management buy-out for non core business	yes/no	13.2	22.4	11.5	4.7	13.5	16.7	7.1
Internal VC fund	yes/no	9.8	14.9	5.8	9.1	26.9	5.6	11.9
Collaboration with external VC fund	yes/no	9.6	10.2	11.3	6.8	15.4	5.6	7.1
Intellectual Property Management								
IP protection competence								
Existence of an active IPR strategy	scale	45.5	57.1	36.5	42.9	59.6	42.3	30.8
Existence of a centralised patent department	scale	44.8	73.5	30.8	28.6	55.8	47.2	26.3
Evaluation process for inventions patenting	scale	36.4	59.2	19.2	31.0	55.8	34.0	13.2
Systematic integration of imitation risk	scale	31.0	41.7	25.0	26.2	42.3	26.9	21.1
IP questions discussed at board meetings	scale	28.5	42.9	19.2	23.3	37.3	32.1	12.5
Scrutiny of competitors' patent applications	scale	25.9	43.8	15.4	18.6	34.6	28.8	10.3
Barriers to patent applications								
Market lead more efficient	scale	59.1	51.4	72.0	57.7	51.5	62.2	66.7
Inability to prevent the copy of the technology	scale	52.5	45.5	54.5	60.0	48.3	65.7	31.3
Not efficient protection, lack of confidence	scale	45.6	41.2	66.7	33.3	29.0	58.8	50.0
Secrecy more efficient	scale	44.0	42.4	47.4	43.5	40.0	55.9	18.2
Too high cost of protection	scale	41.6	35.3	50.0	44.0	41.9	45.5	30.8
Too high cost of fees	scale	38.7	33.3	41.2	44.0	46.7	37.5	23.1
Invention disclosure too risky	scale	35.1	34.4	38.9	33.3	34.5	42.4	16.7
Too short product life cycle	scale	27.3	18.8	38.1	29.2	26.7	29.4	23.1
No information on the patenting process	scale	20.8	7.7	33.3	24.0	15.4	20.6	33.3
Barriers to Innovation								
Potential barriers to innovation assessment	scale	58.7	55.1	62.5	62.8	66.0	58.8	53.8
High innovation or development costs	scale	61.1	55.1	64.0	65.9	58.8	62.7	68.3
High economic risks	scale	58.7	58.3	56.0	63.6	64.0	52.9	61.0
Time constraints	scale	39.3	40.8	37.5	43.2	37.3	39.2	46.2
Lack of financial strength / support	scale	24.8	27.1	18.0	31.8	35.3	16.0	24.4
Resistance to change	scale	24.1	24.5	28.6	20.5	23.5	29.4	20.0
Lack of qualified personnel or competencies	scale	24.1	26.5	18.4	29.5	23.5	21.6	30.0
Inappropriate public regulations	scale	16.6	13.3	26.5	12.5	10.9	14.3	30.8
Customers' organisational rigidities	scale	16.3	15.2	23.9	12.5	12.2	17.0	25.0
Lack of customers' reaction to innovations	scale	15.2	16.3	21.3	9.5	10.0	16.3	23.1
Poor communication inside the BU	scale	13.1	16.7	10.6	13.6	15.7	10.4	15.0
Lack of leadership	scale	10.3	10.4	8.3	14.0	12.2	9.8	10.3
Internal organisational rigidities	scale	8.3	14.6	4.1	6.8	6.0	11.8	7.5
Trade unions	scale	7.6	6.7	17.0	0.0	4.2	8.2	14.7
Lack of access to competent suppliers	scale	6.3	4.3	9.1	7.0	6.1	8.5	5.4
Imperfect protection system	scale	3.6	2.4	5.6	5.4	0.0	9.5	3.8

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Tables and figures to be inserted

Figure 1: Mapping the Innovation Process and its Environment

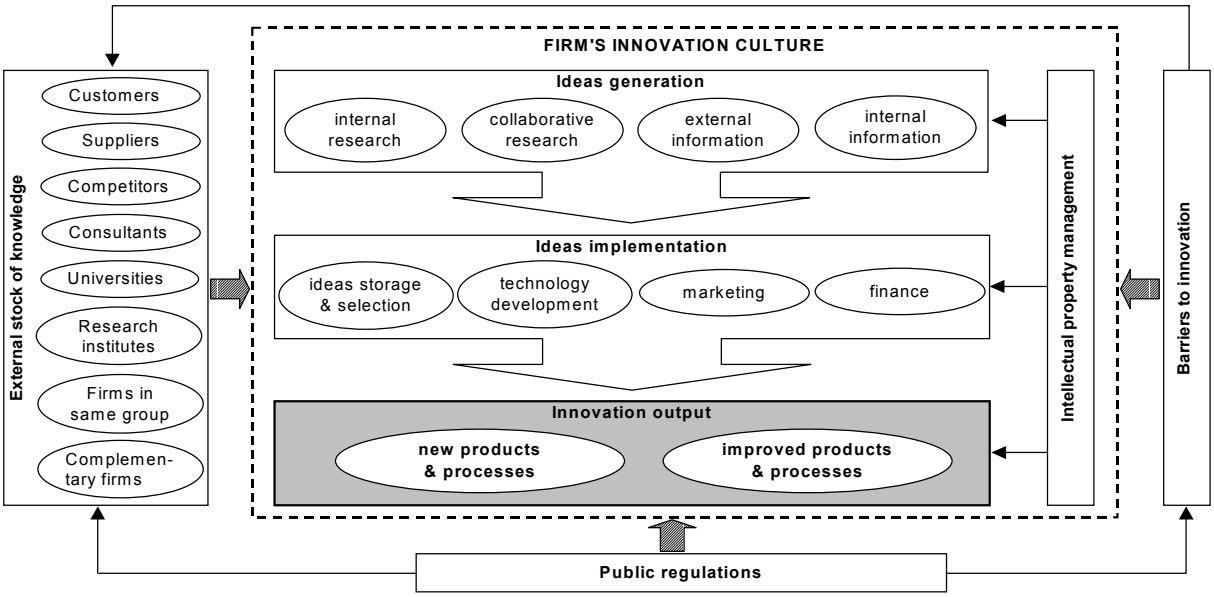

Table 1: Composition of the Final Sample, 148 Firms

% in column *% in row*	HT	MH	ML	LT	SERV	Total
LARGE	21.4 6.1	42.1 36.7	50.0 30.6	29.2 14.3	19.1 16.3	**33.1** **100**
MEDIUM	21.4 5.7	15.8 11.3	36.7 20.8	45.8 20.8	52.4 41.5	**35.8** **100**
SMALL	57.1 17.4	42.1 34.8	13.3 8.7	25.0 13.0	28.6 26.1	**31.1** **100**
Total	**100** **9.5**	**100** **25.7**	**100** **20.3**	**100** **16.2**	**100** **28.4**	**100** **100**

Small firms have less then 200 employees, medium-size firms have between 200 and 499 employees, and large firms have 500 or more employees.

Figure 2 : Average % of sales allocated to basic and applied research and to development activities

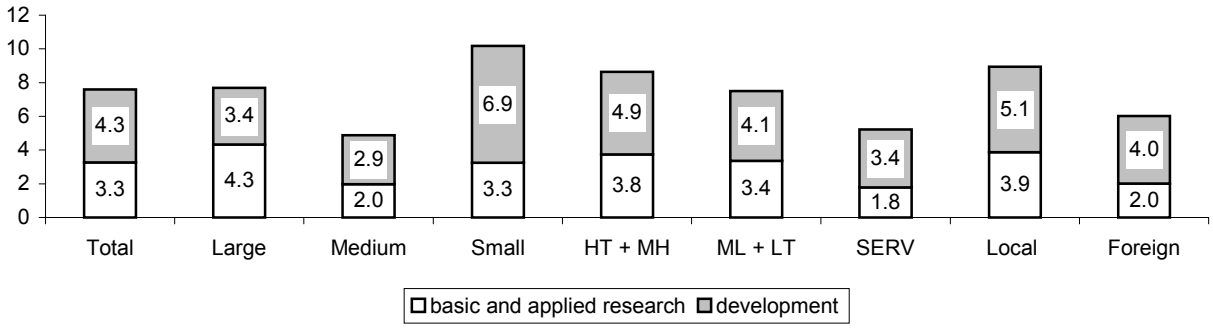

Table 2: Number of firms with a certain # of patent applications in 2000

# patents	More than 100	Between 10 and 100	Between 1 and 10	0
# firms	1	11	36	38

Figure 3: % of firms with at least 1 patent application (by size and technology opportunity)

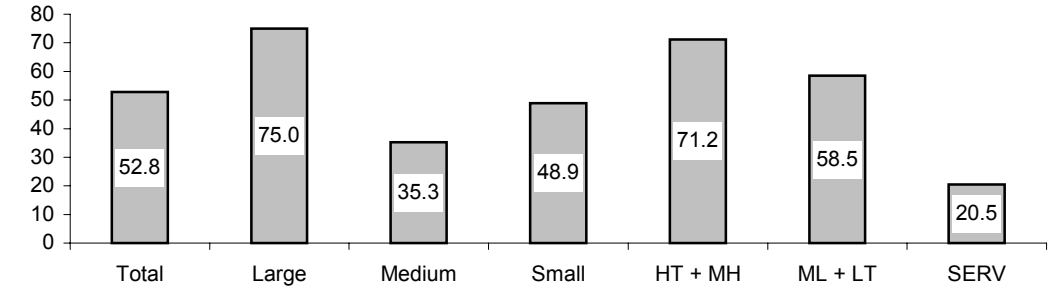

Figure 4: % of patents exploited in the firm own production and % of licensed patents in the patents portfolio

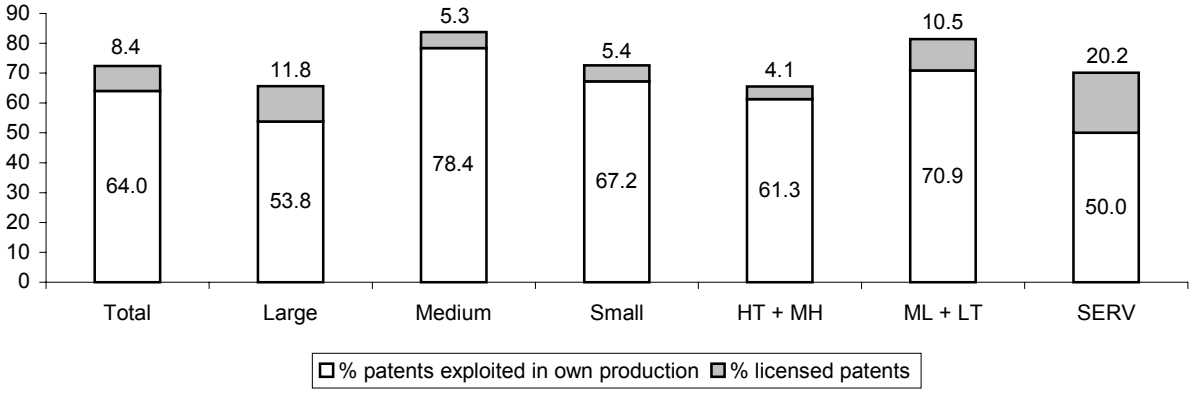

Figure 5: % of turnover due to improved and technologically new products and processes in 2000

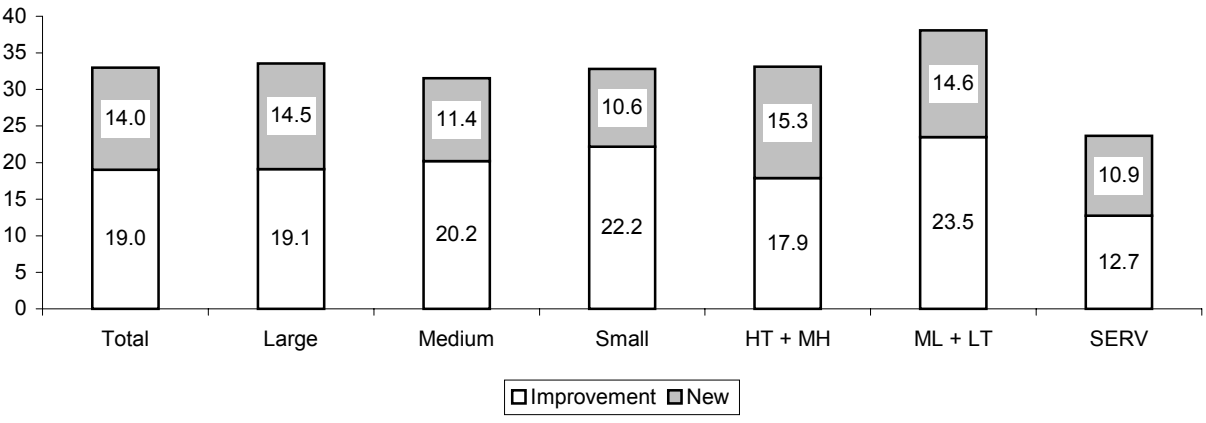

Figure 6 : Culture of innovation development (average % of firms with a 4 or 5 answer on a 0 to 5 scale)

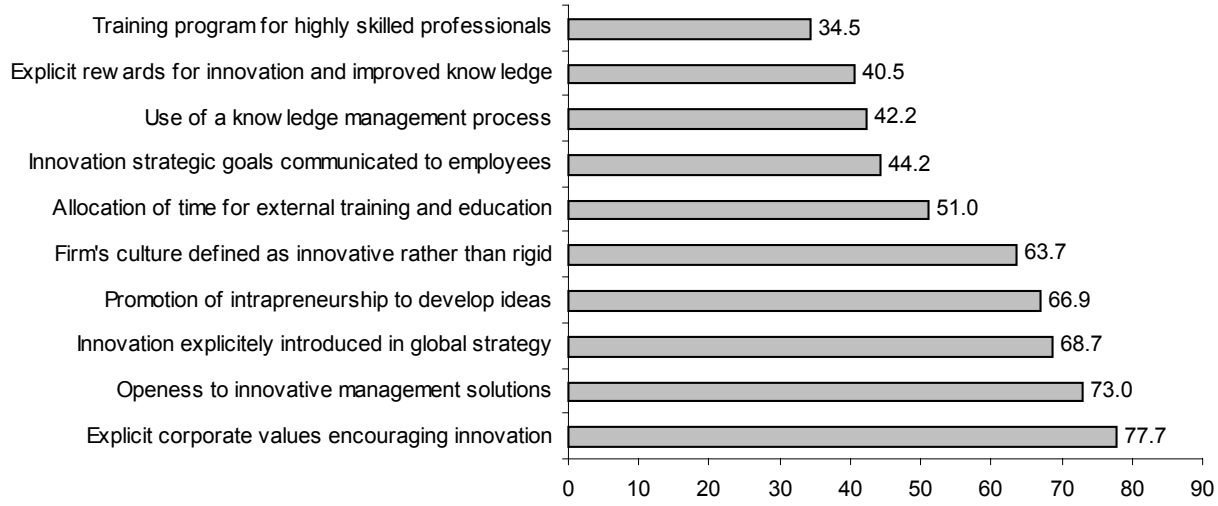

Figure 7 : Importance of various innovation areas (average % of firms with a 4 or 5 answer on a 0 to 5 scale)

Figure 8 : Internal measures to generate ideas (average % of firms with a 4 or 5 answer on a 0 to 5 scale)

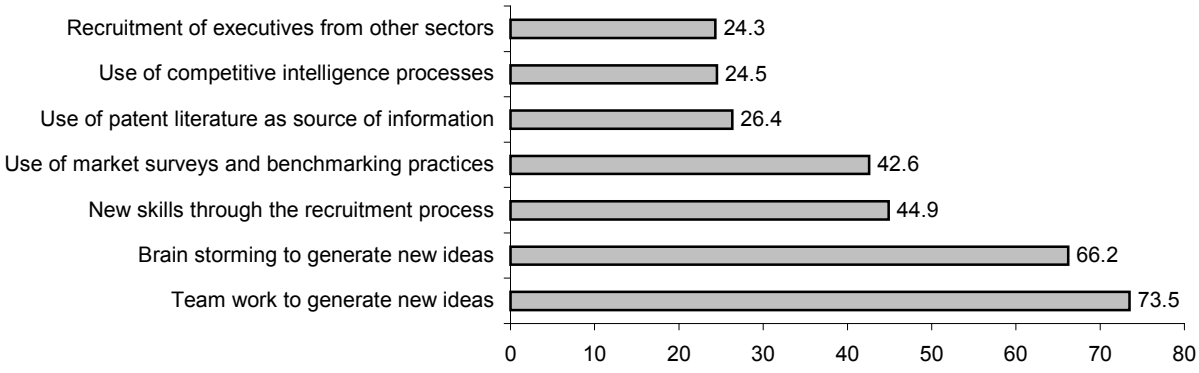

Figure 9 : External information sources (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

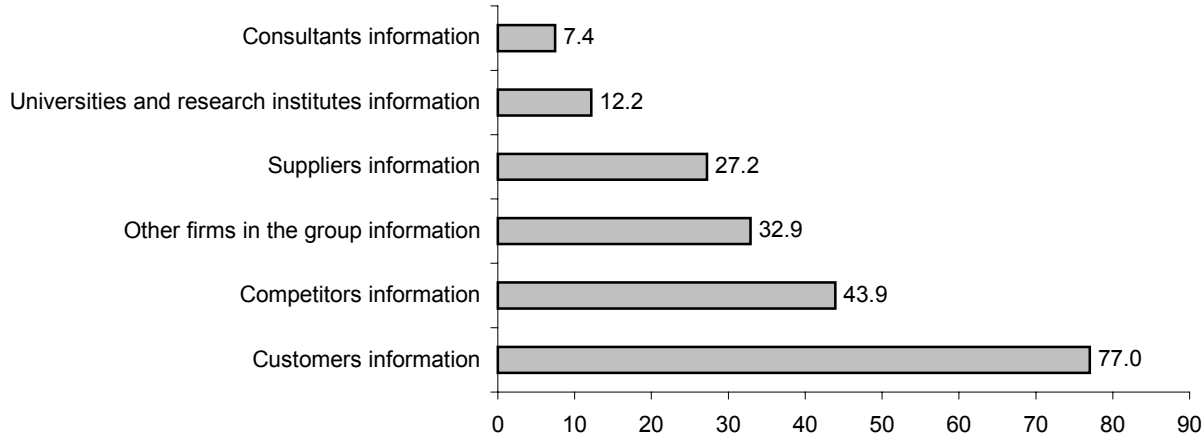

Figure 10 : Average % of firms involved in at least one collaborative research agreement

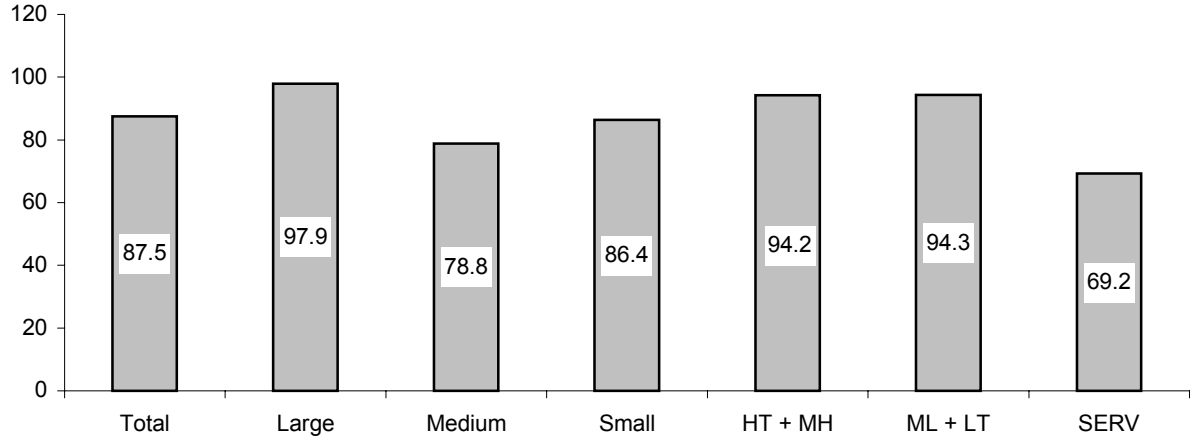

Figure 11 : Average % of firms answering YES per type of research collaboration

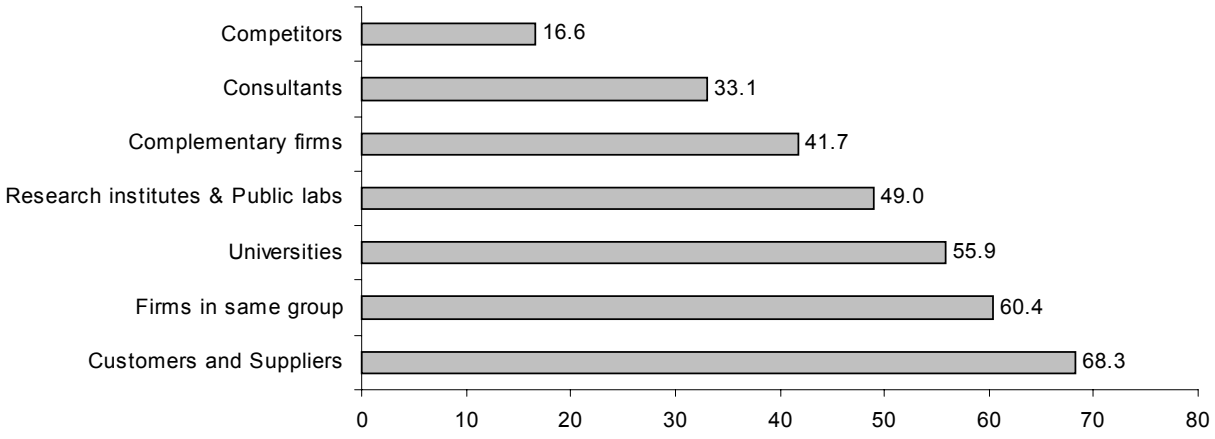

Figure 12: Organisational issues (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

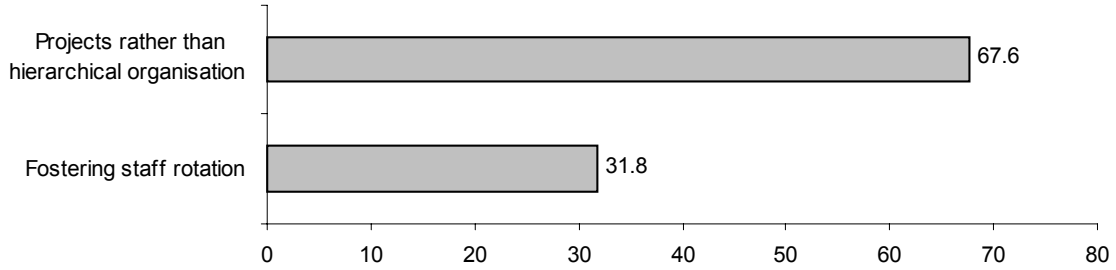

Figure 13 : Ideas storage and selection (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

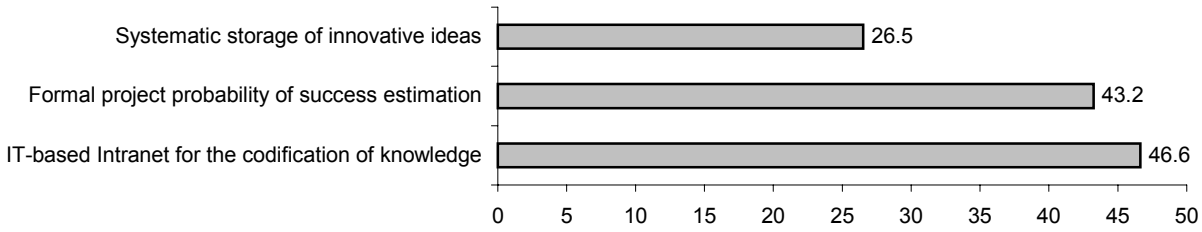

Figure 14 : Average % of firms that buy external technology and/or subcontract some research projects

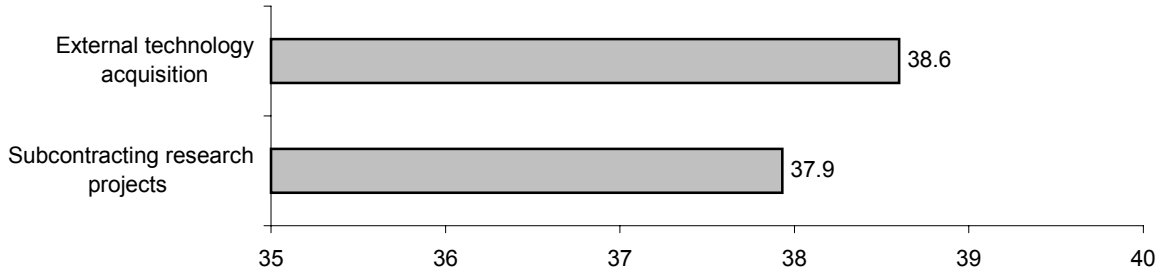

Figure 15 : Innovation marketing (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

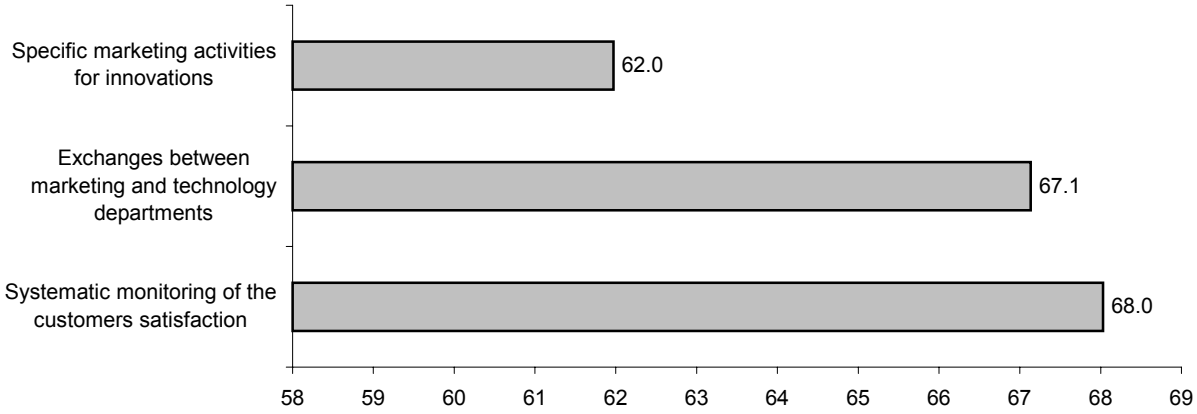

Figure 16 : The innovation funding sources (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

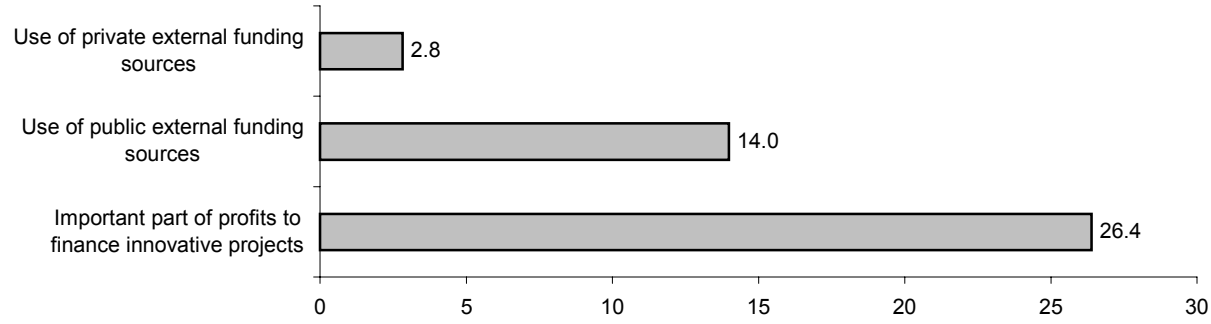

Figure 17: Average % of firms that use VC funds and/or the management buy-out system

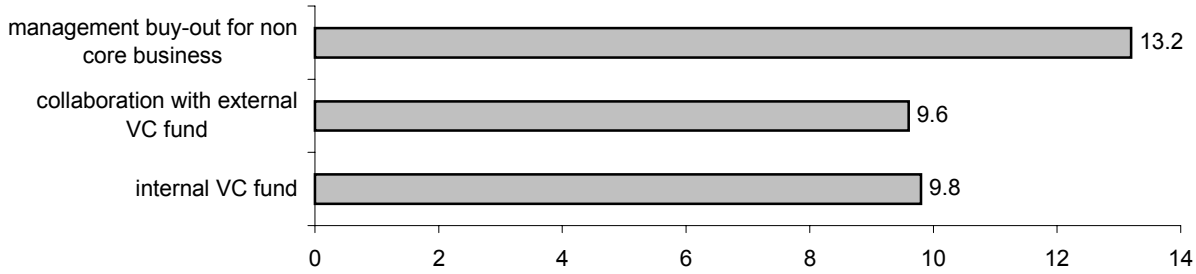

Figure 18 : IP management (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)

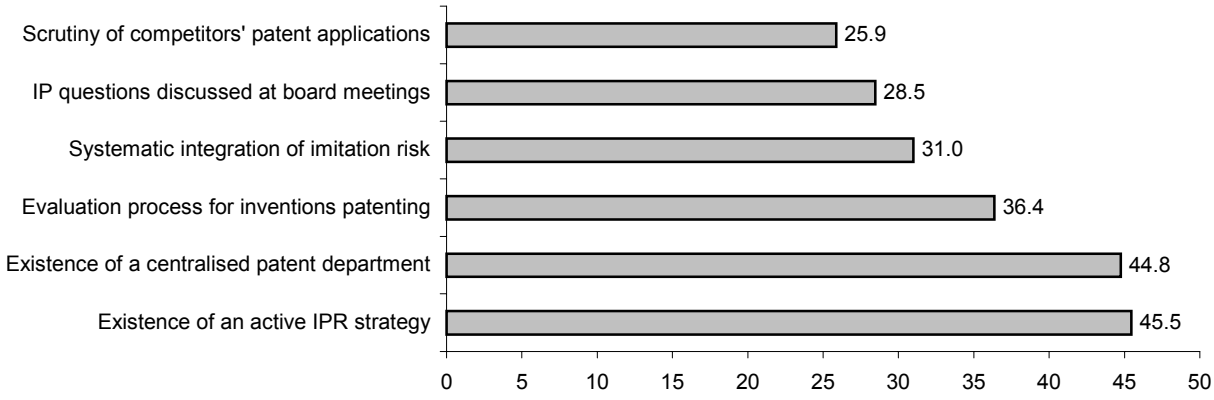

Figure 19 : Barriers to patent applications (average% of firms with a 4 or 5 answer on a 0 to 5 likert scale)

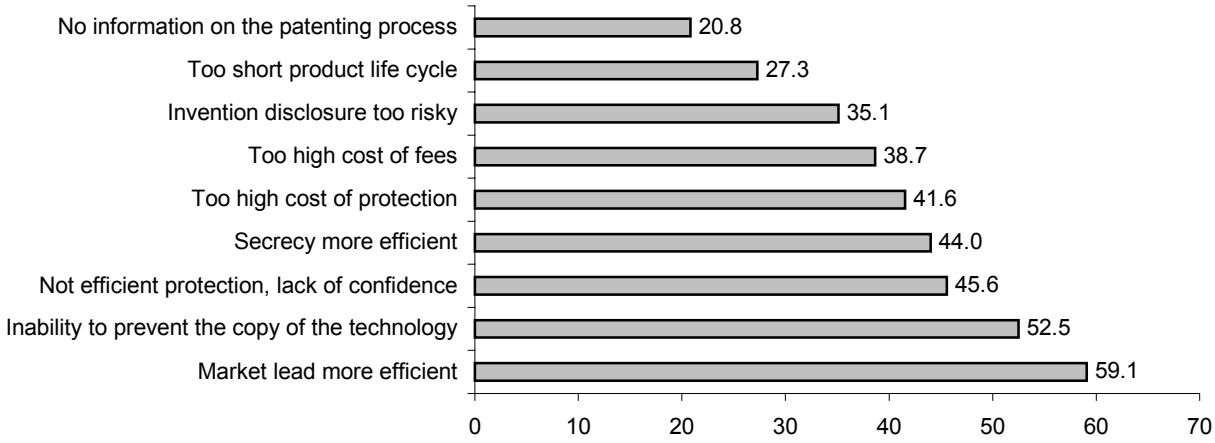

Figure 20: Potential barriers to innovation (average % of firms with a 4 or 5 answer on a 0 to 5 likert scale)