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Industrial Innovation in Finland

An Empirical Study

Ari Leppälahti – Mikael Åkerblom

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Preface

This report presents the results of a study based on the first innovation survey conducted by the Central Statistical Office of Finland (CSO). The survey produced information on the innovation activities of 197 Finnish firms operating in the manufacturing sector. The aim of the study was to add to the knowledge of certain aspects - sources, barriers, costs, outcomes - of the industrial innovation process in Finland.

The Technology Development Centre (TEKES) has given financial support for both the present study and the development of the methodology used in the innovation survey. Without this support, our work in the field of innovation indicators would not have been possible. The innovation survey and this study were carried out in close cooperation with the other Nordic countries. The work has also been stimulated by innovation research in other countries.

This report has been prepared by Senior Researcher Mikael Åkerblom and Planning Officer Ari Leppälahti. An advisory committe chaired by Heikki Havén, Head of Division, CSO, offered valuable suggestions and comments. The other members of the committe were Aarno Laihonen, Head, Statistical Methods, CSO; Timo Airaksinen, Director, Federation of Finnish Metal, Engineering and Electrotechnical Industries; Markus Koskenlinna, Associate Director, Technology Development Centre (TEKES); Alpo Kuparinen, Special Adviser, Ministry of Trade and Industry; Torsti Loikkanen, Head of Division, Technical Research Centre of Finland; Erkki Ormala, Chief Planning Officer, Science and Technology Policy Council of Finland; Keijo Räsänen, Senior Research Fellow, Academy of Finland; and Pekka Ylä-Anttila, Research Supervisor, Research Institute of the Finnish Economy.

The CSO thanks all those who have contributed to the innovation survey and the present study. It is hoped that this report - in addition to containing some new information on the industrial innovation process in Finland - will give a stimulus to further development of innovation surveys.

Helsinki, May 1991

Heikki Havén

Contents

Abstract

Innovation is one of the driving forces of economic growth. In many countries, special innovation surveys have therefore been undertaken in order to get more information on the innovation process than is provided by the statistics of R&D and patents.

The purpose of this study, which is based on the results of the first innovation survey by the Central Statistical Office of Finland, is to increase the body of knowledge concerning the innovation process, especially its non-R&D elements, in Finnish industry. The study focuses on the interconnections of the characteristics of a firm and the innovation process and its output. An attempt is also made to compare the results with those of some other countries and to evaluate the indicators used with a view to the further development of innovation surveys.

The survey was carried out in close co-operation with the other Nordic countries. The results are based on the 1988 data on the innovation activities of 197 firms which engage in R&D. Naturally, the small size of the sample places some restrictions on the interpretation of the results. The survey gathered information on the sources of innovation, barriers to innovation, innovation expenditure and innovation output.

Market factors, such as customers and competition, are the most important sources of innovative ideas. R&D plays a kind of problem-solving role in the innovation process but is not a primary source of innovative ideas.

Excessive risk was considered an important barrier to innovation in about half the firms. Financial problems and lack of technical know-how were important barriers in small firms.

Approximately 40% of the innovation expenditure was accounted for by R&D and the rest by acquisition of technology and new production capacity linked to innovation, start-up of manufacturing, tooling, and marketing of innovations.

Although the proportion of new products in sales is greater in small firms than in large ones, our data suggest that it is more common for large firms than small ones to introduce significant innovations. Foreign competition has an effect on the introduction of innovations

Inter-industry differences proved to be crucial in determining the characteristics of the innovation process. A four-class taxonomy of industries was constructed in order to analyse these differences.

A comparison with the Nordic countries and Germany (for some variables also with the USA and Italy) reveals many similarities as regards the sources of innovation and barriers to it. Market-related sources were more important in Finland and Sweden than in the other countries. Risk and financial problems were among the most important barriers in all countries. The proportion of product innovations in sales was larger in Germany than in the Nordic countries.

The study produced a great deal of useful information about the structure and results of the innovation process. A deeper analysis of the connection between innovation inputs, innovation output and economic performance would, however, require the availability of time series. Data on innovation activities should therefore be collected at regular intervals.

Introduction

Innovation is held to be one of the driving forces of economic growth. The innovation process results in the market introduction of new or substantially improved old products or the launching of new or substantially improved production methods. A better understanding of the innovation process is necessary for policy-making purposes. Decisions on innovation policy have so far been based on a limited amount of information. R&D and patent statistics have been the only regular sources of information.

R&D statistics have been used as an indicator of innovation though covering only one aspect of the innovation process, namely the input of R&D resources. R&D statistics tend to underestimate the level of innovation activities, especially in small firms. Innovation policies often overemphasize R&D, partly because of a lack of information on the other aspects of innovation.

Patent statistics are easily available and have been produced for a long time. Their coverage of inventions does not take into account whether an invention has led to an innovation or not. One problem of using patent statistics as an indicator of innovation activities is that the use of patents varies according to the industry and the size of the firm. The significance of patents also varies greatly. Estimates of innovation activities based on patent statistics tend to underestimate innovation in large firms; there are other means available to large firms for protecting themselves against imitations.

Special innovation surveys have been undertaken in many countries in order to satisfy the obvious need for data on the other aspects of the innovation process. These surveys have also produced information on the output of innovation, which is necessary for evaluating the productivity of R&D.

The innovation surveys have been of two kinds. Some concentrate on a set of successful innovations, trying to determine what factors underly the innovations. This approach was pioneered by the Science Policy Research Unit of Sussex University in England, where a database has been compiled on successful innovations introduced in the UK. The database has proved highly useful for different kinds of analysis. The same approach has been used in Canada, by de Bresson (OECD 1990a), and in Finland, by Lovio (1988) in a study on innovation in the electronics industry.

The other survey approach tries to analyse the whole of a firm's innovation process regardless of whether it has led to a successful result or not. Surveys of this kind were pioneered by the IFO institute (Institut für Wirtschaftsforschung) in Munich, Germany, where they have been carried out annually since 1979. This approach has also been used in the innovation surveys carried out in the USA, Italy and Austria.

Innovation surveys conducted in different countries have been presented and discussed at various OECD seminars dealing with output indicators in science and technology. The latest seminar, focusing on innovation indicators, was held in 1986.

Partly inspired by the international developments presented at this seminar, the Central Statistical Office of Finland set up a pilot project in this field in 1988. This was made possible by a research grant from the Technology Development Centre (TEKES). The aim of the pilot project was to determine the feasibility of collecting quantitative data on the innovation activities of Finnish firms. The approach chosen was thus the same as in Germany, Italy, the USA and Austria.

The experiences of these countries were carefully examined and the national need for information was explored. A pilot questionnaire was then designed and tested in interviews with about 20 firms. As the general survey approach seemed to work quite well, the questionnaire was revised in light of the experience gained from the interviews. A report on the results of the Finnish pilot project was published in the spring of 1989 (CSO 1989).

It was then decided to undertake a more comprehensive pilot survey in 1989. One aim of the survey was to further test the survey instrument and to get information for its improvement. Questionnaires were sent out to 377 firms, 197 of which supplied information that could be used in the analysis of the results. As it was difficult to get information from firms that did not pursue R&D, only information from firms pursuing R&D was included in the analysis. Naturally, the modest size of the sample has imposed some restrictions on the analysis and should be taken into account when interpreting the results of this study. Details of the sampling procedure can be found in the Appendix 2 to this report. The first preliminary report on the Finnish innovation survey was published in the spring of 1990 (CSO 1990). The report contains a short summary of the main results of the survey.

As the next step, the results were subjected to a more detailed analysis supported by a grant from the Technology Development Centre. The present report presents the results of this study.

The aims of the study were:

— to increase the amount of information available on the innovation process in Finnish industry;

— to study the connections between the characteristics of a firm and the innovation process and its output;

— as far as possible, to compare the results with corresponding results obtained in other countries;

— to evaluate the indicators used in the survey so as to provide a basis for further improvement of the innovation survey.

All stages of the survey work took place in close co-operation with the other Nordic countries, where similar surveys were under way. The results of the Nordic work were published in June 1991 (Nordic Industrial Fund 1991).

To harmonize the innovation surveys of different countries, the OECD is developing a recommendation for a conceptual framework, definitions, questions and classifications to be used in innovation surveys. Finland and the other Nordic countries have actively participated in the drafting of the OECD recommendation. A first draft of the recommendation is available (OECD 1990b), with the final recommendation scheduled for publication in 1992.

This report has five chapters:

Chapter 1 illuminates the theoretical background of innovation indicators by presenting a descriptive model of the innovation process.

Chapters 2 and 3 present the empirical results of the survey. The main topic of chapter 2 concerns the connections between the different characteristics of the firm and the various aspects of the innovation process and its output. Chapter 3 analyses inter-industry differences with the help of a taxonomy of industries.

Chapter 4 contains some international comparisons, primarily with the Nordic countries as based on the Nordic report, but also with Germany, Italy and the USA.

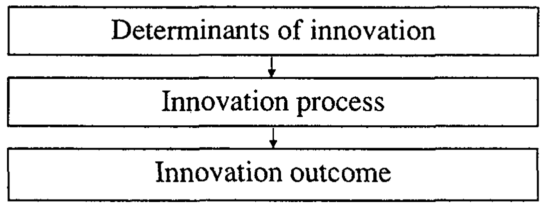
Chapter 5 contains a short conclusions of some of the results.

A technical description of the data and the sampling procedure is presented in the Appendix, along with the survey questionnaire and a set of more detailed tables.

1. Theoretical background

In the treatment of technological change in economic theory, no comprehensive theory or model has yet been constructed of innovation that would allow empirical testing (see, for example, Coombs 1987, Freeman 1982, IVA 1990). The theoretical framework in this field consists of various concepts and hypotheses which still need to be integrated into a comprehensive theory. Next, to provide a basis for the construction of various indicators, an attempt is made to present a descriptive framework of the innovation process suitable for subsequent empirical analysis. One aim of innovation surveys is empirically to verify certain inter-relationships within the innovation process that can later be used for theory building in this field.

The model consists of three parts:



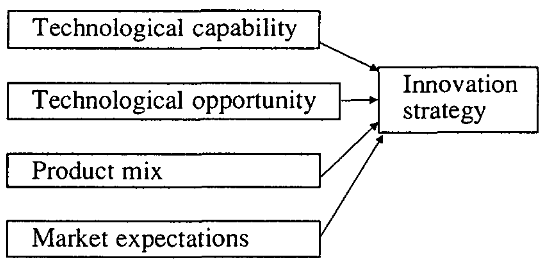
The elements of each part will be described separately. It is important to stress that there is continuous interaction and feed-back between the different parts of the system.

1.1 The determinants of innovation

The point of departure of the model is provided by the firm's competitive behaviour (see, for example, Smith 1989). The competition is technological in two ways. First, firms compete in terms of the design, quality and performance characteristics of products in order to meet changes in consumer demand. Second, they compete in terms of process technology, which shapes both the technical form of products and the cost structure of firms.

The development of a firm's product and process technology strategies is based on the firm's expectations about consumer demand and actions by competitors. The strategies may change over time and are influenced by the results of the innovation process. In addition, they may vary from one product group to another in the same firm.

The strategies depend on a set of factors which can be described with the help of the following figure:



A firm's **technological capability** refers to its knowledge base resulting from historically shaped learning paths. It depends on the firm's earlier technological activities and the skills of its personnel.

A firm's **technological opportunities** are the opportunities open to the firm within a specific set of relevant, historically and technically determined design and production parameters (technological trajectory). Technological opportunities change as the level of learning changes within the firm (due to both R&D and non-R&D activities) and as progress is made in technological development external to the firm.

A firm's **product mix** refers to the distribution of sales of the firm's products by the phase of the product life-cycle. According to the portfolio theory developed by the Boston consulting group, a firm should aim at an optimal distribution between the different phases of the life cycles of its products. Usually, a greater proportion of sales should be generated by products in the introductory phase than by products in the decline phase. Cases conflicting with this principle should serve as an incentive to innovation.

Market expectations are, of course, an important determinant of a firm's innovation strategy. Innovation activities are more likely to occur in fields associated with positive market expectations. Expectations about competitors' actions and the price development of production factors also play a role.

These are the determinants a firm uses when deciding, *implicitly or explicitly*, on the types of market it will serve and on the types of innovation it will aim at on these markets. A firm has to choose an optimal combination of the following options available (OECD 1990b):

R&D-based:

— to undertake basic research in order to extend its knowledge base;

— to undertake strategic research (with industrial relevance but without specific applications) or applied research in order to produce specific inventions or modifications of existing techniques;

— to develop product possibilities to a stage of commercial feasibility, involving prototype design, development and testing, and sometimes further research to modify designs or technical functions;

Non-R&D-based:

— to define new product possibilities and production technologies through marketing, design and engineering, monitoring of competitors, or use of consultancy;

— to develop pilot and full-scale production facilities;

— to undertake development work based on buying technology (royalties, technological information, etc.)

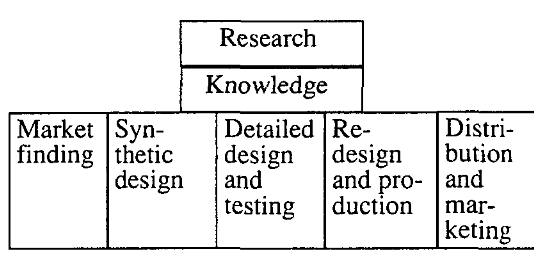
— to develop human skills through internal training or by hiring personnel with relevant skills, also including possible tacit and informal learning (learning by doing);

— to invest in process equipment or intermediate inputs embodying the innovation activities of others, ranging from components to machines and entire plants;

— to reorganise management systems and overall production systems and methods.

1.2 The innovation process

The process of innovation can be described using various models, such as the chain-link model constructed by Kline (Kline 1987). As appears from its description in the figure below, Kline's model mainly describes product innovation but can also be applied to process innovation.



The innovation process usually starts from a market finding, i.e. an assessment of what might improve a given product or system, or provide a new product or system that will meet an unfulfilled market (use). Market findings may come from various sources of innovative ideas (top management, internal R&D, marketing, production, customer demand, competitive situation, co-operation with other firms or research institutes or universities, etc.). Market findings often result from feed-back from the subsequent stages of the innovation process. Market findings for specific products or processes also constitute a determinant of the firm's overall innovation strategy.

The first step in the innovation process consists in the construction of a synthetic design. This is usually the general layout or model of a new design, a new synthetic arrangement of the product, process or system created largely from old components or items within the existing state of the art.

The next step of the innovation process is concerned with development, i.e. detailed design and manufacture of prototypes and performance of tests. The development phase often requires changes in the original inventions or preliminary designs.

After the development phase, the new product or process is fixed enough to allow a decision to be taken on its introduction. This leads to the next phases of redesign and production (i.e. tooling, industrial engineering and manufacturing start-up), and distribution and marketing. These phases also include acquisition of the software and hardware, and provision of the training, necessary for the introduction of the new products and processes.

The intrinsic feature of the chain-link model is the existence of various links between all the different phases and the role of research in the innovation process.

The most important links are as follows:

(1) The first type links the various phases together. The knowledge developed in the early stages of work is usually crucial to success in the later stages.

(2) The second type links the distribution and marketing phase back with all the previous phases. An error discovered in a product on the market may involve work in any or all of the prior stages along the chain of innovation. Assessment of product utility and competitiveness may lead to new market findings and can be part of the planning and design of later models or new systems for a given purpose.

The role of research in the chain link model is that of problem solving. The factor analysis of different sources of innovation described in chapter 2 seems to support this conception. Problems arising during the synthetic design, detailed design, or redesign and production phases are at first solved by consulting the firm's knowledge base. The knowledge base is the result of earlier research or the accumulation of technical and practical experience. If the necessary information is found, it is applied to the relevant design phase. If it is not found, research must be activated. Naturally, research can also be an important source of innovation by contributing to a market finding or to a synthetic design.

The innovation process is also affected by various general factors contributing to the success of innovation projects or to various barriers to innovation.

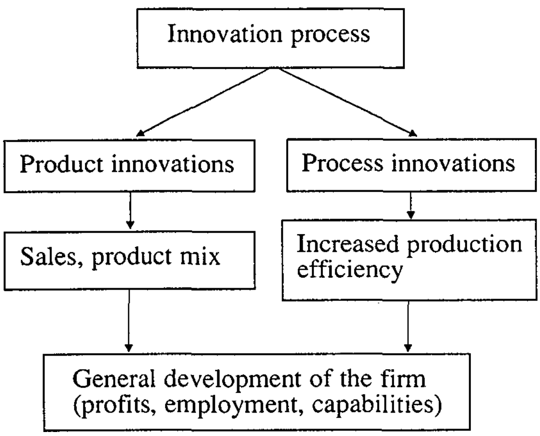
Examples of factors contributing to the success of innovation projects include co-operation of R&D with marketing and production, contributions of top management, and co-operation with other firms or research institutes or universities.

Examples of barriers to innovation include excessive risk, lack of funding, gaps in the quality of internal R&D, lack of qualified personnel, resistance to change, and inadequate availability of external services.

Factors contributing to the success of innovation projects are often the same as barriers to innovation, though seen from a different point of view. For example, lack of qualified personnel is a barrier to innovation, while a good supply of qualified personnel and other key persons is often a factor contributing to success.

1.3 The output of innovation

The output of innovation can be described with the help of the following figure:



The immediate results of the innovation process are product innovations or process innovations.

Product innovations include new or substantially improved products (major product innovations) and performance improvements to existing products (incremental innovations).

Major product innovations consist of radically new technologies or are based on existing technologies put to new uses.

Incremental product innovations also take two forms. Firstly, a simple product may be improved by using more efficient components or materials. Secondly, a complex product consisting of a number of integrated technical subsystems may be improved by making partial changes in one or more of the subsystems.

Process innovations consist in the adoption of new or significantly improved production methods. These may involve the whole process or consist of improvements to some parts or features of the process.

Product innovations influence the firm's sales. In most cases sales will increase. The product mix of the firm will be altered in that an increased proportion of sales will be generated by products in the introductory phase.

Process innovations influence the firm's production costs, and the efficiency and flexibility of production will increase.

Innovations influence the firm's long-term overall development, profitability in particular. The effects of failed innovations may be negative. Again, there are numerous feedback links to earlier parts of the innovation process

Explicitly or implicitly, innovations often give an impetus to further innovation work by improving the firm's technological capabilities and opening up new technological opportunities.

2. Characteristics of the innovation process

As noted above, the innovation process is shaped by a complex interplay of several factors. In this chapter, various characteristics of the innovation process are analysed in relation to certain characteristics of the firm, such as size, R&D intensity, industry, export orientation and market position.

Size is classified according to number of personnel: small firms 1-99 employees, medium sized firms 100-499 and large firms 500- employees (for definition of small R&D intensive group, see Appendix 2). Classes of R&D intensity are: low intensity R&D expenditure less than 1% in sales, medium intensity 1%-4% and high intensity over 4%.

2.1 Innovation strategies

As explained in chapter 1, a firm responds to changes in its technological and economic environment by working out some new strategies. The strategies also influence the firm's innovation activities by defining what kinds of market the firm will compete on and what types of product and technological improvement it will aim at.

In our survey, three sets of questions were asked about innovation strategies:

— Technological strategies,

— Strategies concerning new markets and new products,

— Strategies concerning the use of certain input factors.

Four alternatives were given for each question. An evaluation of the importance of each alternative was requested on a scale from 1 (not important) to 4 (important) and 5 (very important).

The most common technological strategy was to improve the firm's existing technology. This strategy was considered important (proportion of choices 4 or 5) by 80% of the firms. About 60% considered development of new technology for the industry as important (see table 2.1). Perhaps surprisingly, this strategy was rated lowest by large companies.

The strategy of new products for the present markets was considered important by nearly 80% of the firms. Nearly half the firms considered the development of new products for new markets as important. This alternative, which can be considered the most active of product strategies, appealed more to small firms than to large ones.

A more efficient use of the existing inputs was considered important by over 80% of the firms. Labour cuts were considered important by two-thirds of the firms (see table 2.3 below). Energy conservation was relevant only for large companies.

Table 2.1
Technological innovation strategies: proportions of respondents rating a factor as important

	N	Development of technology new for the industry %	Further development of technology developed by others %	Utilization of technology developed by others %	Improvement of firm's existing technology %
ALL	**197**	**60.0**	**49.5**	**57.9**	**79.9**
Size					
Small R&D intensive firms ..	27	66.7	48.0	50.0	76.9
Small firms	55	62.2	51.9	60.4	77.2
Medium-sized firms	62	61.0	47.1	54.7	86.2
Large firms	53	51.4	49.4	62.1	76.1

Table 2.2
Market and product strategies: proportions of respondents rating a factor as important

	N	Present products, present markets %	New products, present markets %	Present products, new markets %	New products, new markets %
ALL	**197**	**56.4**	**77.7**	**50.1**	**45.0**
Size					
Small R&D intensive firms ...	27	44.0	54.2	69.2	62.5
Small firms	55	59.1	78.7	53.4	54.4
Medium-sized firms	62	54.4	76.1	46.1	33.1
Large firms	53	59.7	88.0	42.4	41.5

Table 2.3
Strategies concerning selected inputs: proportions of respondents rating a factor as important

	N	Use of new inputs %	More efficient use of existing inputs %	Energy conservation %	Labour cuts %
ALL	**197**	**61.9**	**81.5**	**19.1**	**66.3**
Size					
Small R&D intensive firms ...	27	50.0	72.0	4.2	40.0
Small firms	55	60.9	79.0	17.3	72.9
Medium-sized firms	62	66.4	85.2	17.0	65.1
Large firms	53	61.5	84.5	32.2	66.1

2.2 Sources of innovation activities

The discussion about sources of innovation centres on three hypotheses, namely those referred to as 'technology push', 'demand pull' and 'learning by doing' (see, for example Coombs 1987, Freeman 1982).

The 'technology push' hypothesis of innovation is derived largely from the ideas of Schumpeter. According to Schumpeter, generation of whole new industrial sectors is possible only through the introduction of radically new ideas into the economy. Technology to Schumpeter is the leading engine of economic growth.

The 'demand pull' hypothesis is mainly derived from the empirical work that Schmookler did in the sixties concerning the connection between investment in capital goods and patents. According to Schmookler, the scope of the potential market is the key determinant of innovation activities.

The 'learning by doing' hypothesis introduced in recent research is, in a way, a combination of the previous two hypotheses. According to this approach, acquisition and application of technology combined with the cumulative learning resulting from its use will lead to further technological development.

The question of the origins of innovations has been the subject of many empirical studies. These have shown that demand (or need) is often the most important determinant of technological change. Thus, awareness of user needs coupled with efficient communication and collaboration are strongly associated with successful innovations.

However, it is not possible to conclude that 'demand pull' is a more important source of innovation than 'technology push'. On the other hand, it is obvious that both factors are important determinants of success in innovation activities. According to Freeman (1982), 'technology push' tends to be more important in the early stages of development of an industry, while 'demand pull' tends to grow in relative importance during the mature stages of the product cycle.

As our innovation survey starts from the innovation activities of a firm as a whole, it has not been possible to trace the development of individual innovations. In addition, firms that produce a variety of products may have had difficulties in reporting the importance of a particular source of innovative ideas. Thus, the figures provided should be interpreted as weighted averages for each source appropriate from the firm's point of view.

According to Hippel (1988), sources of innovative ideas may also be influenced by the relationship between the type of firm and innovation (user, manufacturer, supplier of components to be used in innovative products).

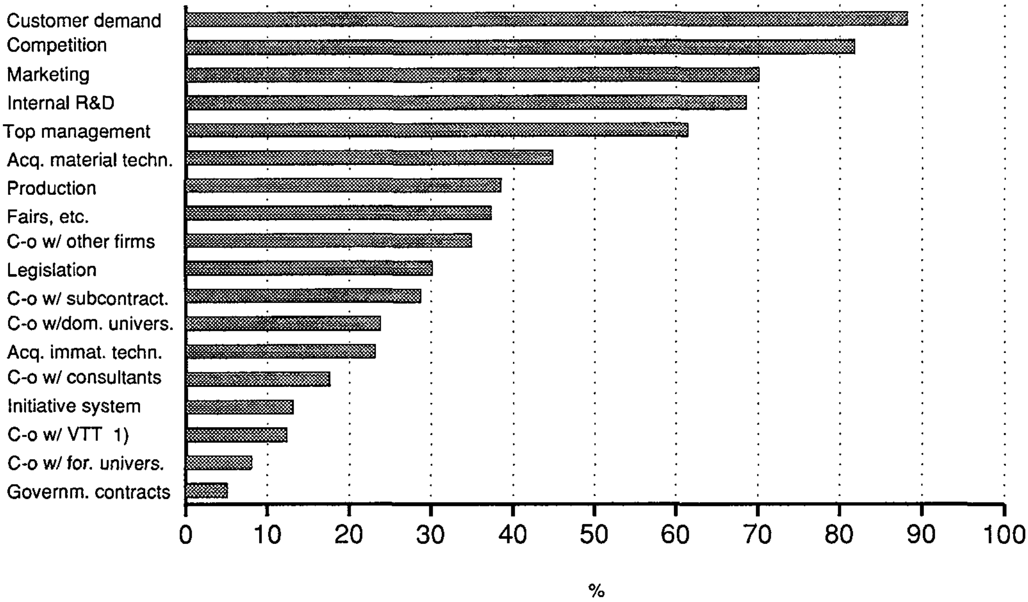
In the questionnaire, a list of 18 factors were given as possible sources of innovative ideas. Figure 2.1 shows the sources as ranked according to the percentage of respondents considering them important (i.e. scores 4 and 5).

Market-related sources dominate, technology-related ones lagging clearly behind.

This finding must be treated with caution. Because we are operating at the level of individual firms, it may be argued that at least some information on the demand for a new product is a precondition for a competitive firm to innovate at all. In the chain-link model described in chapter 1, a market finding was the starting point of innovation.

According to Mowery and Rosenberg (1979), technology-related factors tend to be caricatured as purely scientific events, free of any economic component whatsoever. The role of technological factors in generating commercially successful innovations tends therefore to be underestimated.

Figure 2.1
Sources of innovation ideas: proportions of respondents rating a factor as important



1) Technical Research Centre of Finland

Given these objections, we should be cautious in drawing the conclusion that market demand is the dominant source of innovations.

Appendix tables 1a-c show the proportions of respondents considering a particular source of innovative ideas as important according to a set of selected characteristics of firms. The main results can be summarized as follows:

(i) Production (which can perhaps be taken to represent cumulative learning) is more important to medium and low R&D intensity firms than to high R&D intensity firms.

(ii) High R&D intensity firms get fewer ideas from the competitive situation than do low and medium intensity firms.

(iii) Acquisition of material technology is more important to low and medium R&D intensity firms than to high intensity firms.

(iv) Co-operation with both domestic and foreign universities is more important to large firms than to medium-sized or small firms.

(v) Internal sources, such as top management and production, are more important in the case of units with a modest level of exports.

Factor analysis can be used to find out whether our set of questions can be summarised in a meaningful way or, which amounts to the same thing, whether there are some "hidden" concepts to which our set of 18 sources of innovation is related in a systematic way.

Our analysis produces three factors. Although variance explained by these factors is not very high, 41.5% (see Appendix 3), the results of the analysis are interesting.

A crucial step in factor analysis is the interpretation and naming of the factors. It has even been claimed that factors can nearly always be interpreted to fit the theory. However, the interpretation of our factors seems straightforward enough:

1. Scientific and technological co-operation
2. Production-related ideas
3. Market-related ideas

These factors fit the existing models of sources of innovation quite nicely. The first factor reflects 'technology push', the second accumulated 'learning by doing' and the third 'market pull'. None of the factors dominates over the others, as can be seen from the small differences between the variances explained by each factor. **This indicates support for the hypothesis that, at the macro level, industrial innovations originate from the interaction of several sources.** In the case of an individual innovation, one source is usually dominant. Different types of innovation usually originate from different sources.

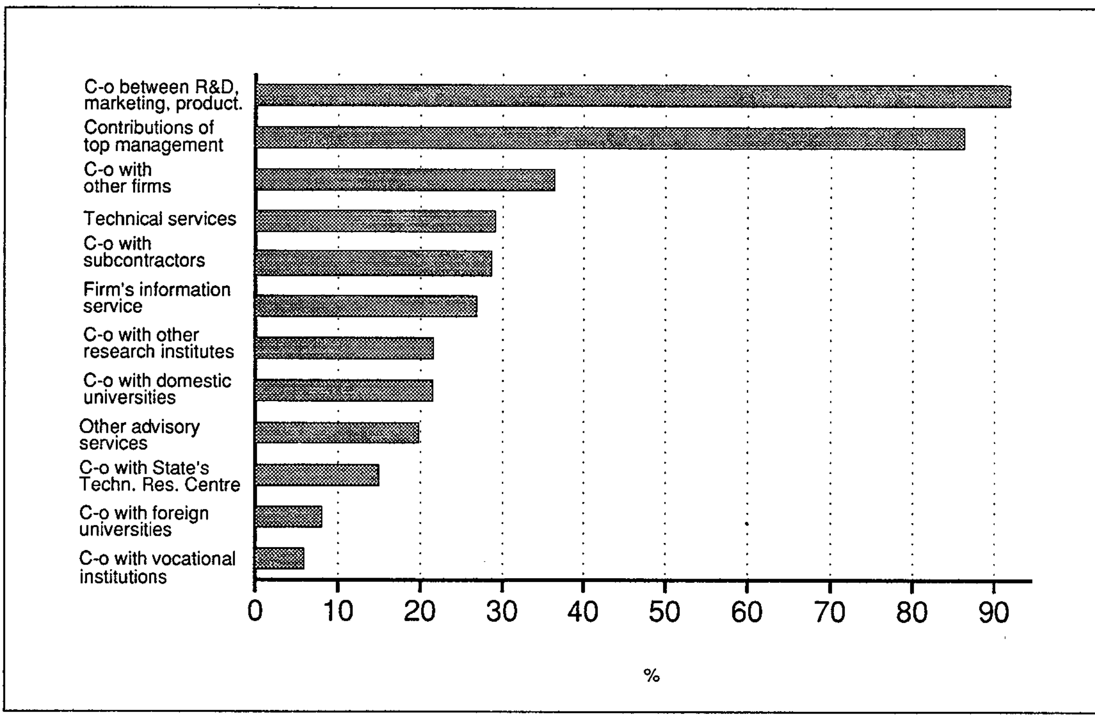
The role of internal R&D is particularly interesting. R&D has rather low loadings on any of the three factors (Appendix 3), including the second factor which reflects technological know-how. **This is consistent with the hypothesis in the chain-link model described in chapter 1, according to which R&D is a kind of problem-solving mechanism and not the main source of ideas in the innovation process, i.e. a mechanism that can be called upon in any stage of a product's development (see p. 10 above).**

From the point of view of government technology policy, co-operation with public research institutes (mainly the Technical Research Centre of Finland) and universities is perhaps the most interesting factor. The results of factor analysis suggest the **cumulative nature of co-operation with universities and research institutes as a source of innovation.**

Universities are more important sources of innovation than research institutes, even though the level of co-operation between firms and research institutes is much higher as measured by the money spent by firms (see figure 2.1).

In another item of the questionnaire, information was asked about the importance of various factors contributing to the success of innovation efforts. In figure 2.2, factors promoting innovation are presented in the same way as ideas. As expected, **co-operation between marketing, R&D and production is the most important factor,** while the **high rating of the contribution of top management,** 86%, is perhaps surprising. Co-operation with other industrial companies, the third factor, lags clearly behind, at 36%. As in the case of ideas, co-operation with universities and research institutes (other than the Technical Research Centre) is more important to large firms than to small firms.

Figure 2.2
Factors promoting innovation: proportions of respondents rating a factor as important



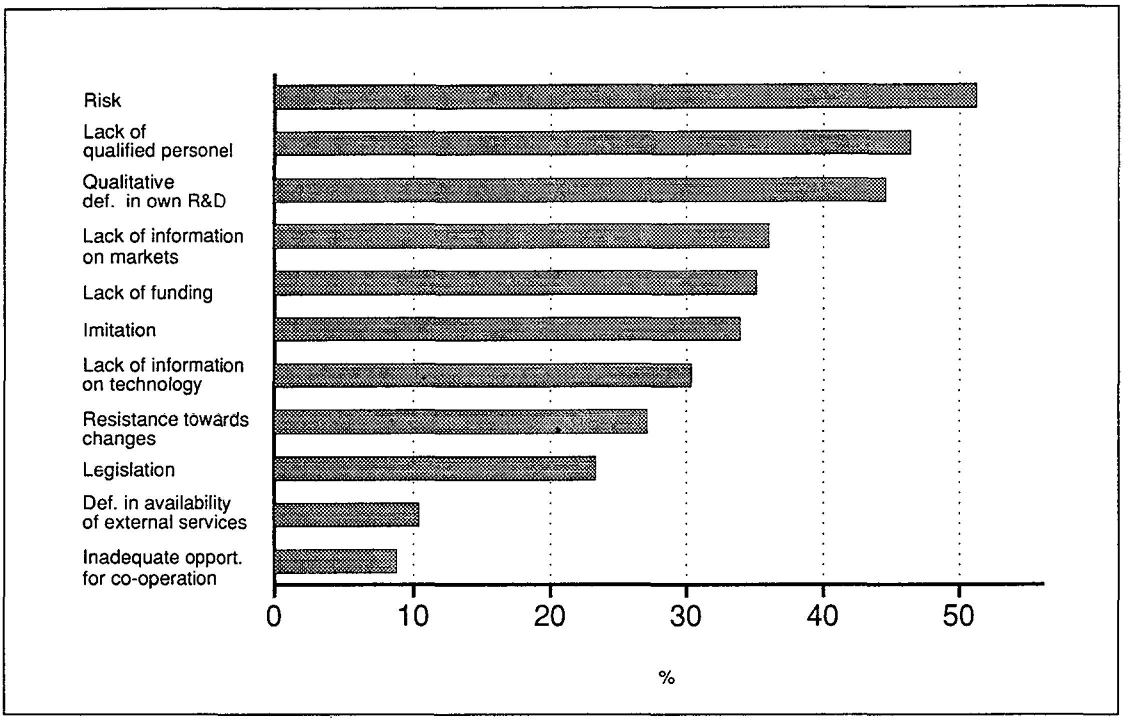
2.3 Barriers to innovation activities

Like sources of innovative ideas and factors promoting innovation, there are also obstacles to innovation. These may be internal or external to the firm and may vary in importance depending on the firm's financial or technological resources.

In our study, barriers to innovation were operationalised in the same way as ideas. In order to identify the most important factors that hinder a firm from developing and introducing innovations, the firms were presented with a list of eleven assumed barriers to innovation. Perhaps because of the structure of our questions or, simply, the lack of comprehensive theoretical models, factor analysis did not produce as straightforward results as in the case of ideas. Therefore, we will here focus on those characteristics of firms that seem to explain the most interesting differences. The importance of different barriers to innovation is presented in figure 2.3. Barriers to innovation according to the characteristics of firms are presented in Appendix tables 2a-c.

(i) Lack of funding is a problem of small R&D intensive firms in particular. Similarly, inadequate information on technology is more of a problem for small R&D intensive firms than for other groups.

Figure 2.3
Barriers to innovation: proportions of respondents rating a factor as important



(ii) Lack of qualified personnel is more of a problem for high and medium R&D intensive firms than for low R&D intensive firms.

(iii) Lack of market information is emphasized by firms with a high level of exports (over 50% of sales), whereas qualitative deficiencies in internal R&D are more of a problem for firms with a more modest level of exports (less than 50% of sales).

2.4 The scope of innovation activities

The scope of the innovation process appears from the following information on innovation expenditure, the length of R&D projects, R&D co-operation and trade in technology.

2.4.1 Innovation expenditure

The question on innovation expenditure was designed to determine the firm's innovation budget, i.e. its total expenditure on innovation activities regardless of whether the activities had led to innovations or not. The innovation budget covers R&D expenditure as defined in general R&D statistics and non-R&D innovation expenditure consisting of the following four items:

— Acquisition of technology

— Application of innovations

— Marketing of innovations

— Acquisition of new production capacity

In general, giving information on innovation expenditure was rather difficult for firms. Firms that did not record other innovation expenditure than R&D expenditure had to estimate it. In addition to the difficulties in reporting other innovation expenditure, respondents found it difficult to classify it into the categories defined above. Some firms only supplied information on the total of other innovation expenditure. Given this, the distribution by type of other innovation expenditure is based on information from a rather limited number of firms. Furthermore, in interpreting the data, it should be borne in mind that they only cover companies engaging in R&D.

These expenditure items do not cover indirect innovation expenditure or costs incurred in building up an infrastructure for innovation activities, i.e. education expenditure in general and the cost of acquiring qualified personnel.

R&D expenditure as a proportion of total innovation expenditure was about 40%. R&D intensive enterprises exhibit the largest proportion of R&D expenditure (figure 2.4). Size also seems to affect R&D expenditure, small firms showing the smallest proportion of R&D expenditure (figure 2.5).

Other innovation expenditure is dominated (73%) by the acquisition of new production capacity (figure 2.6). There is reason to suspect that this item is somewhat overestimated because of a vague definition. Firms have included a large amount of investment expenditure in this item (especially in the pulp and paper industries) though it is questionable that all of it has gone for innovation purposes. This problem makes the whole distribution random indeed. If, for example, one unit with a large investment program is excluded, the proportion of acquisition of new production capacity will diminish to 54%.

In high R&D intensity firms, a considerably smaller proportion of other innovation expenditure is accounted for by the acquisition of new production capacity than in medium or low intensity firms. On the other hand, high intensity firms spend more on the acquisition of technology and on the marketing of innovations than the other two groups (table 2.4).

Again, exclusion of one major "investor" would alter the figure for the low R&D intensity group considerably.

2.4.2 Other aspects of the innovation process

The questionnaire also asked for information on the number of R&D projects at the end of the year according to the expected length of the project and on the participation of the firm in R&D co-operation or trade in technology.

Figure 2.4
R&D expenditure in proportion to total innovation expenditure according to R&D intensity

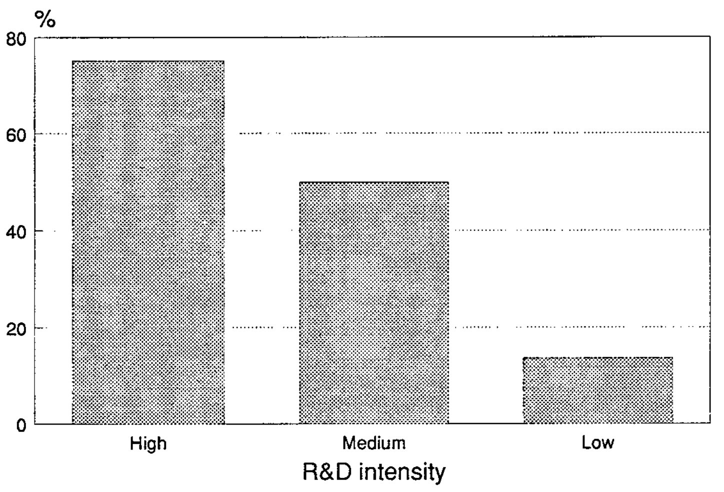


Figure 2.5
R&D expenditure in proportion to total innovation expenditure according to size of firm

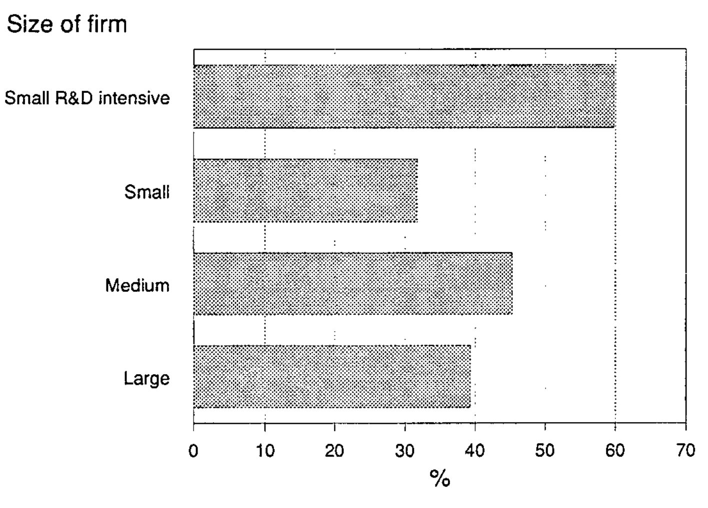


Figure 2.6
Distribution of other innovation expenditure

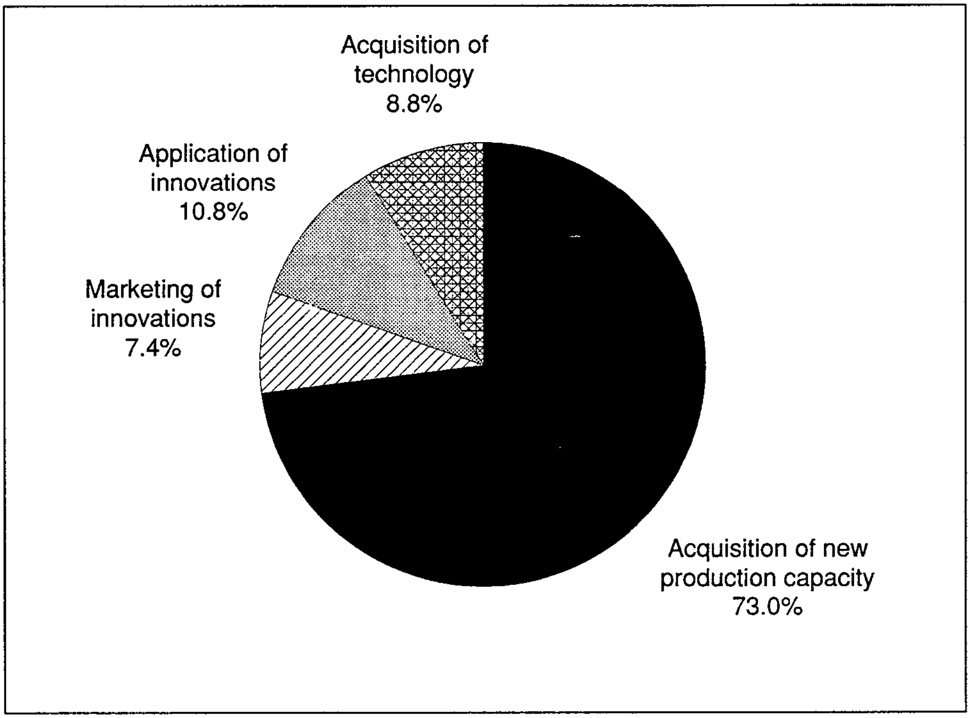


Table 2.4
Distribution of other innovation expenditure according to R&D intensity

	N	Acquisition of technology %	Application of innovations %	Marketing of innovations %	Acquisition of new production capacity %
ALL	**100**	**8.8**	**10.8**	**7.4**	**73.0**
R&D intensity					
High R&D intensity	29	24.3	17.9	18.5	39.3
Medium R&D intensity	44	16.8	21.0	8.8	53.4
Low R&D intensity	27	2.3	4.9	4.7	88.1

Large companies seem to be better equipped to undertake long-term R&D projects than small and medium-sized ones. As appears from table 2.5, large companies averaged 1.1 R&D projects with an estimated duration of more than five years. The corresponding figures for small and medium-sized companies were only 0.2 and

0.1. R&D projects lasting over five years are intrinsic to the chemical industry, 3.7 on the average.

Large companies lead small ones in R&D co-operation, both in Finland and abroad. Nearly all large companies participated in R&D co-operation, compared with 70% of small firms. The Nordic countries and the EC accounted for the majority of foreign research contacts of Finnish firms (table 2.6).

As pointed out earlier, co-operation with universities and research institutes as a source of innovation ideas was more important to large firms than to small ones. This is also reflected in the frequency of research contacts (table 2.7): large firms had more research contacts than small or medium-sized firms. It should be pointed out, however, that this measures only the occurrence vs. non-occurrence of co-operation and not its scope or effects, which may well be more important to small firms than to large ones.

Large firms are also more active in all forms of trade in technology, especially in sales (Appendix table 3). About one-third of all firms had bought technical consulting services from Finnish consulting firms. One-fourth had bought methods of production containing new technology. Sales of technology were less common. Only 7% had sold a license to a foreign country.

Table 2.5
Number of R&D projects in progress according to duration

	N	1 year or less	1 – 2 years	2 – 5 years	Over 5 years
ALL	**197**	**5.4**	**3.0**	**1.7**	**0.4**
Size					
Small R&D intensive firms	27	1.3	0.6	0.4	0.2
Small firms	55	1.3	0.6	0.5	0.1
Medium-sized firms	62	3.2	2.0	0.9	0.1
Large firms	53	14.2	7.8	4.4	1.1

Table 2.6
Research co-operation according to country group

	N	No participation %	Finland %	Nordic countries %	EC %	USA %	Japan %	Other %
ALL	**197**	**17.1**	**79.7**	**21.9**	**23.6**	**12.1**	**5.1**	**5.9**
Size								
Small R&D intensive firms	27	14.8	81.5	7.4	14.8	7.4	7.4	3.7
Small firms	55	30.3	65.1	10.5	3.8	3.9	0.0	1.5
Medium-sized firms	62	11.2	85.3	24.5	31.4	10.9	4.7	3.6
Large firms	53	1.5	98.5	47.0	54.6	32.8	14.9	19.4

Table 2.7
Research co-operation according to research partner

	N	Other units in the same concern %	Other industrial firms %	Consults %	Research institutes %	Universities %
ALL	**197**	**33.2**	**40.3**	**49.2**	**44.9**	**34.4**
Size						
Small R&D intensive firms	27	11.1	40.7	29.6	33.3	37.0
Small firms	55	17.0	22.7	44.1	31.6	11.9
Medium-sized firms	62	38.7	39.9	49.0	42.6	41.1
Large firms	53	66.5	76.1	68.6	80.5	67.1

2.5 Characteristics of firms and innovation output

2.5.1 The measurement of innovation output

The need for more comprehensive data on the output of the innovation process has given a major impetus to the development of innovation surveys. The immediate outputs of innovation activities comprise product and process innovations. The mere number of new products or processes cannot, however, be used as an indicator of innovation output since products and processes are incommensurable across industries, even across firms. Thus, the number of new products or processes can only be used as a measure of innovation output when considered in relation to the total number of products or processes in the firm.

In our survey, three indicators were used to measure the output of product innovation:

— The proportion of sales generated by products in their introductory phase (PPI);

— New products as a proportion of the total product base (PNP1);

— The proportion of sales generated by new products (PNP2).

New products comprise product innovations introduced on the market during the past five years.

In addition to PNP2, some tables also show exports generated by product innovations in proportion to total exports.

PPI is based on the life-cycle model of a product, in which the life cycle of a product is divided into four phases:

1) Introduction
2) Growth
3) Saturation
4) Decline

The claim has been made that the proportion of sales generated by products in the introductory phase indicates the result of a firm's innovation activities. The IFO institute in Germany and others have argued that this indicator provides a more precise measure of the actual innovation output than the other indicators do because, unlike them, it is not influenced by diffusion factors

(OECDb). The different time spans - one year for PPI, five years for the other indicators - cause differences in results. In fact, PNP1 and PNP2 include products that are no longer innovations as they are already in the growth or saturation phase and are being diffused to other sectors.

There is a clear positive correlation between PNP1 and PNP2. PPI also correlates positively with the other two indicators, but the connection is weaker (table 2.8).

Table 2.8
Correlations of output indicators

	PPI	PNP 1	PNP 2
The proportion of sales generated by introductory phase (PPI)	1.0		
New products as a proportion of the total product base (PNP 1)	.17	1.0	
The proportion of sales generated by new products (PNP 2)	.20	.62	1.0

There is a clear connection between these output indicators and the firm's main branch of economic activity. Industries like food, pulp and paper, and chemicals exhibit the lowest values. Electronics, electrical machinery, and machinery and transport equipment are above the average (Appendix tables 4a-c). PPI behaves a bit differently in that electronics, computers and instruments, in particular, show surprisingly low values.

2.5.2 Size of the firm and innovation output

The connection between the size of the firm and innovation has been the subject of somewhat conflicting hypotheses. On the one hand, large firms are assumed to be more innovative than small firms because they can take advantage of the economies of scale in R&D and are better able to bear the rising cost of innovation (see, for example Coombs et al. 1987, Kamien & Schwartz 1982). On the other hand, small firms are assumed to benefit from their greater flexibility afforded by their more effective internal communication. In addition, researchers' incentive to innovate might be better in a small-firm environment.

The connection between the size of the firm and innovation has been analysed in several empirical studies. Most of them have tried to establish a connection between R&D intensity and the size of the firm, implying that R&D intensity is in direct proportion to the outcome of innovation. This has in no way been verified and is still a moot point. Even more direct difficulties of interpretation exist. Given the same percentage of sales allocated to R&D, the economies of scale may give large firms a greater relative benefit than they give to small firms. Innovation surveys like ours, which include questions on the output of innovation may throw some light on this question.

Empirical evidence suggests that R&D intensity tends to grow with the size of the firm up to a certain point, after which it will decrease. This hypothesis has been rejected by Soete (1979), who claims that R&D intensity does not decrease after a certain size has been reached.

For all three output indicators, the results of our survey give small R&D intensive and other small firms the highest values (Appendix tables 5a-c).

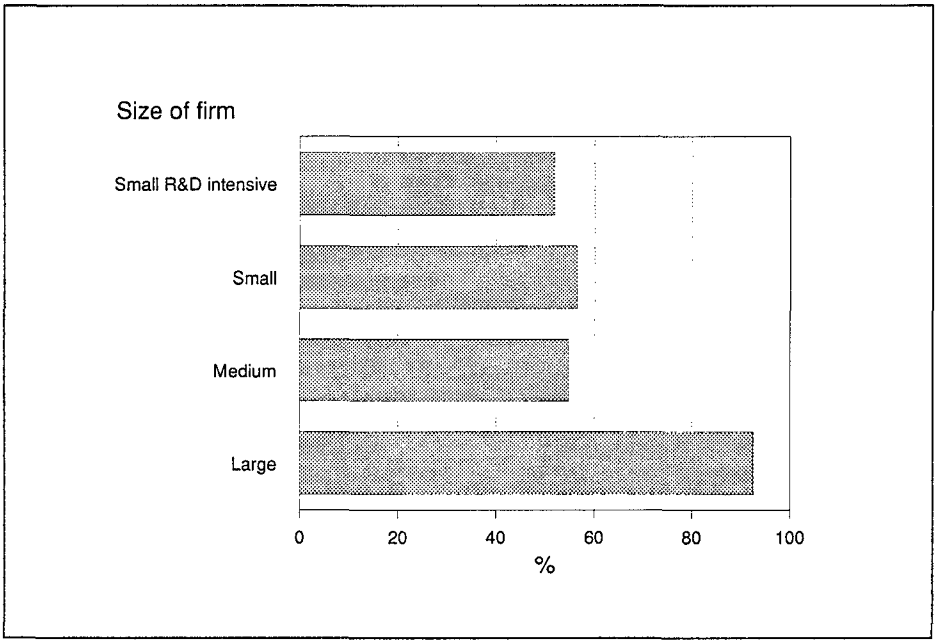
To obtain comparable data by size, firms less than five years old have been excluded from the analysis. The high values of small firms for these indicators may be explained by the small number of articles in their product base, which naturally increases the importance of individual product innovations. In addition, many small firms are born around a particular product concept embodying the technological know-how of the firm. This accumulated know-how then contributes to the further development of the product idea and provides a basis for the firm's competitive advantage. Further, if one is ready to assume that large established firms "make their money" from a wide variety of diversified products, or from the volume of sales of a few core products renewed rather infrequently, then one should be careful about using the proportion of new products as an indicator of innovation output.

Another aspect of the outcome of the innovation process concerns new production methods. Unfortunately, the only information available to us about process innovations relates to the application or non-application by the unit of a new production process or new production methods during the past five years. (Our survey did include a question on the number of process innovations, but it had to be omitted because of data collection problems.)

From figure 2.7, the conclusion can be made that almost all large firms have introduced process innovations and that small R&D intensive firms depend more on product innovations.

The foregoing indicators only measure the scope of the innovation output in terms of new products and processes, with no reference to quality. There are a number of studies the focus of which is on the technological content and degree of novelty of a specific innovation. In our survey, information was requested concerning the whole of the firm, making it impossible to provide detailed information on the qualitative characteristics of the innovations introduced.

Figure 2.7
Proportions of firms reporting process innovations by size of firm



Thus, what we have is the number of product innovations which, as far as the responding unit has been able to ascertain, no other company has introduced before (e.g. products new for the market). Table 2.9 demonstrates that, as regards the size of the firm, small R&D intensive firms exhibit the largest proportion of products new for the market, while firms in the other size groups are at roughly the same level. Table 2.10 suggests that, as regards the connection between this indicator and R&D intensity, **high R&D intensity firms exhibit the largest proportion of products new for the market.**

One straightforward method for analysing the scope and the degree of novelty of innovation activities is to combine different criteria. Following Archibugi et al. (1991), we expect a highly innovative unit to meet the following three conditions: 1) introduction of a product new for the market, 2) introduction of a process innovation, 3) possession of at least one important source of innovative ideas internal to the firm (top management, internal R&D, production, marketing, system for initiatives from employees). These factors reflect the quality, scope and endogenicity of innovation activities, respectively. **As table 2.11 shows, large firms are the most innovative as measured by this method.**

We have also tried to determine the connection between market expectations and reproduction of the product base, i.e. the elasticity of production with respect to the anticipated demand for final products.

In the questionnaire, respondents were asked to evaluate the expected growth in the demand for their three most important product groups over the next five years using a three-stage scale: 'increase', 'remain unchanged' and 'decline'. Leaving aside the problem of obtaining adequate information

Table 2.9
New products in proportion to product innovations according to size of unit

	N	%
ALL	**168**	**30.0**
Size		
Small R&D intensive firms	15	48.5
Small firms	50	30.7
Medium-sized firms	53	24.5
Large firms	50	29.4

Table 2.10
New products in proportion to product innovations according to R&D intensity

	N	%
ALL	**168**	**30.0**
R&D intensity		
High R&D intensity	45	39.0
Medium R&D intensity	68	30.0
Low R&D intensity	55	23.1

Table 2.11
Proportion of highly innovative firms according to size of unit

	N	%
ALL	**197**	**33.7**
Size		
Small R&D intensive firms	27	25.9
Small firms	55	26.1
Medium-sized firms	62	31.6
Large firms	53	56.1

on which to base predictions, it turned out that the expectations were overwhelmingly positive (perhaps due to the boom prevailing at the time). Therefore, we have constructed a dummy variable by connecting 'remain unchanged' and 'decline'. PPI is the indicator for changes in production (a response variable) because it shows the distribution over one year and thus adjusts to changes in demand more rapidly than PNP1 and PNP2 do (both of which span a period of five years).

The proportion of sales generated by products in the introductory phase shows no striking differences between the two classes of expectations. However, when the distribution is further broken down by the size of the unit, it appears that small and medium-sized firms are more apt to react to the perceived changes in demand. This result is by no means surprising, for adjusting the product base is likely to be less costly for small firms than for large ones, simply because of the scope of production (see table 2.12 below).

Table 2.12
Sales accounted for by products in the introductory phase in unit's three most important product groups by size of unit and market expectations

	N	Market expectations	
		Demand expected to decline or remain unchanged	Demand expected to increase
		Sales accounted for by introductory phase	Sales accounted for by introductory phase
		%	%
ALL	**189**	**6.1**	**5.8**
Size			
Small R&D intensive firms	25	20.1	39.6
Small firms	54	5.5	10.0
Medium-sized firms	58	1.7	5.4
Large firms	52	7.6	5.6

2.5.3 Export orientation and innovation

Factors affecting a firm's innovation activities include the nature and intensity of competition and expectations about the development of demand for the firm's main product groups. In a small open economy like Finland, the relevance of foreign competition is obvious. However, it should be noted that some Finnish industries, such as food, construction materials and printing, are essentially protected against foreign competition. But the core of manufacturing in Finland faces foreign competition, especially export-oriented companies.

Traditionally, it is emphasized that the competitive advantage of a small country and its small firms (small on the world scale) lies in specific know-how, e.g. the high technology in a restricted field of production. Thus, it may be argued that this puts pressure on export-oriented firms to continuously improve their products. Industry-specific features should, however, not be forgotten. For example, because of its intrinsic reliance on process innovations rather than product innovations, pulp and paper, one of Finland's biggest export industries, is not very innovative in terms of our output indicators PPI, PNP1 and PNP2 described above.

We have analysed the effects of the degree of export orientation on innovation activities by dividing exports as a proportion of sales into four classes: no exports, 1-25%, 25-50% and over 50%.

In terms of the output indicator PPI, the non-exporting group differs strikingly from the other three groups, the proportion of the introductory phase being only 1.6%. PNP1 and PNP2 reveal similar results, although PNP2 also gives the 25-50% group a rather low figure (Appendix tables 6a-c).

Thus, we have found some support for the hypothesis that the degree of a firm's export orientation influences its innovation activities. The stronger the pressure of market demand, the more rapid the renewal of products.

2.5.4 Market position and innovation

According to Schumpeter, firms in a monopoly position have certain advantages concerning innovation. Preventing imitation of innovations is easier for firms in a monopoly position than for others - by means such as patents, copyright ownership, trademarks, and control of distribution channels. Internal funding is also easier, as is the hiring of competent people (see for example Kamien, Schwartz 1982).

Monopoly position and lack of competition are also associated with certain disadvantages. Quantities of resources may be used solely for the purpose of maintaining the status quo. Firms in a monopoly position tend to become bureaucratised, making it difficult for them to introduce certain types of innovation. On the other hand, it has been argued (Schumpeter 1943) that even if there is no price competition, new technology will eventually threaten market positions based on old technology.

The connection between market structure and innovation has been examined in many empirical studies. Because of theoretical and methodological problems, however, these studies have not reached agreement concerning this connection.

A firm's market position varies depending on the product group. In our questionnaire, firms were asked to supply data on the market share and competitive situation of their three most important product groups. Table 2.13 shows the distribution of sales of these product groups by the phase of the product life cycle (PPI) according to whether the most important competitor on the domestic market was foreign or domestic (including the rather rare cases of "no competition"). As can be seen, the distribution is clearly altered by foreign competition: the proportion of sales generated by products in the introductory phase is larger for product groups facing foreign competition. According to the results by the output indicator PNP1, the proportion of new products in the total number of products is about 37% for products

Table 2.13
Distribution of sales according to phases of product life cycle by competitive situation in Finnish markets

	N	Phase of life cycle			
		Introduction %	Growth %	Saturation %	Decline %
ALL	**355**	**5.9**	**35.7**	**50.3**	**8.0**
Competition					
Domestic competition ...	254	4.6	33.8	53.7	7.9
Foreign competition	101	10.0	41.5	40.2	8.3

with mainly domestic competition and 47% for those with foreign competition. The figures should be treated with caution, however, because of the different time spans: PNP1 measures development during the past five years, while competition is considered in terms of the present time.

An obvious drawback of this indicator is that it is about competition on the domestic market only. We can safely assume that if there is foreign competition on the domestic market, there is also foreign competition on the markets abroad.

Another way to study the effects of market structure is to divide the distribution of sales by the phase of the life cycle according to the product group's share of the domestic market (table 2.14). Perhaps surprisingly, the effect of market structure on the distribution of sales by the phase of the product life cycle is slight, the only exception being that there is an increase in the growth phase as the market share diminishes.

Table 2.14
Distribution of sales according to phases of product life cycle by market position in Finnish markets

	N	Phase of life cycle			
		Introduction %	Growth %	Saturation %	Decline %
ALL	**375**	**6.3**	**35.7**	**49.6**	**8.5**
Market share					
Over 90%	42	6.4	23.5	64.8	5.3
50% – 90%	101	8.9	36.9	42.9	11.3
Less than 50%	232	5.0	38.6	48.6	7.9

In table 2.15, these two indicators are cross-tabulated using the proportion of products in the introductory phase as the output indicator. It can be seen that foreign competition is crucial; market share, or the degree of monopoly, has a weaker effect. It is interesting to note the very low value of 1.2% for monopolies protected from foreign competition. This supports the allegations of inefficiency levelled against monopolies, a subject much discussed in Finland recently.

Thus, it seems that the presence/absence of foreign competition on the domestic market influences the introduction of product innovations.

Table 2.15
Sales accounted for by products in the introductory phase in Finnish markets by competitive situation and market position

	N	Sales accounted for by introductory phase	
		Domestic competition %	Foreign competition %
ALL	**314**	**4.8**	**11.9**
Market share			
Over 90%	30	1.2	12.9
50% - 90%	86	8.0	11.8
Less than 50% ...	198	4.4	10.4

3. Inter-industry differences

As mentioned in several connections above, the sector of a firm's principal activity exerts a crucial influence on the firm's innovation activities. In principle, then, each industry should be considered separately and classes constructed that are homogeneous with respect to the important characteristics influencing innovation activities. In our study, the size of the sample does not allow division even at the two-digit level of industrial classification.

On the other hand, empirical studies have found considerable similarities between different groups of industries, a finding which has led to the compilation of taxonomy models of innovation activities. Pioneering analytical work was done by Keith Pavitt (Pavitt, 1984).

A basic concept dividing industries according to the characteristics of their innovation activities is the technological trajectory, a concept which defines the directions of technical development that are both cumulative and self-generating. The technological trajectory may develop without repeated reference to the economic environment external to the firm, an aspect which constitutes an important modification of the neoclassical models based on the adjustment of factors of production in response to price fluctuations. The technological trajectory can be defined in terms of the following three elements of Pavitt's taxonomy:

1) Sources of technology
   Internal R&D, production and engineering department, suppliers, users, research institutes and universities

2) User needs
   Relative importance of price vs. performance of products and processes

3) Means to appropriate the benefits
   Secrecy, technical lags in imitation, patenting, unique knowledge and skills of innovating firm

Pavitt bases his taxonomy on an analysis of the SPRU database on significant innovations in the UK. He distinguishes between:

1) Supplier-dominated firms

2) Production-intensive firms
   a) Scale-intensive
   b) Specialized suppliers

3) Science-based firms

Pavitt's approach has stimulated a great deal of research and is thus worth discussing at some length here, although it cannot readily be confirmed by our data.

Firstly, Pavitt defines process innovations as innovations used in the same sector in which they are produced and product innovations as innovations used in a different sector from their sector of production. In our approach, a product innovation is a new product (implicitly assumed to be a final product sold to the customer) and a process innovation is a new production method. (For detailed definitions, see Questionnaire in the Appendix 3).

Secondly, in Pavitt's analysis there are three properties attributed to each innovation, namely the sector of production of the innovation, the sector of use of the innovation and the sector of the innovating firm's principal activity. Thus, Pavitt's approach is extremely illuminating in describing the flows of technology into and out of a particular industry and also in describing the balance between innovations "imported" and "exported in a sector. Our data lack the information on the user of the innovation, which considerably limits the possibility of studying the technological diversification and diffusion of innovations.

Thirdly, Pavitt's analysis is based on significant innovations, while ours is based on innovation activities of individual business units.

Another taxonomy approach is provided by an Italian research group (see Archibugi, Cesaratto and Sirilli 1991). The Italian survey resembles ours more closely in that it is also based on business units and treats product innovations in much the same way as we do. However, analytically it has much in common with Pavitt's taxonomy.

As a further development of the Italian approach, we have constructed a four-class taxonomy for empirical testing:

1) Producers of traditional consumer goods
   — Food, beverage and tobacco
   — Textiles
   — Wearing apparel, leather goods and footwear
   — Wood and wood products
   — Publishing and printing
   — Furniture
   — Other manufacture

2) Producers of intermediate goods
   — Pulp, paper and paper products
   — Rubber and plastic products
   — Glass, clay and stone products
   — Basic metal industries

3) Specialized suppliers
   — Fabricated metal products
   — Machinery and equipment
   — Instruments and fine-mechanical apparatus
   — Transport equipment

4) Science-based firms
   — Chemicals and chemical products
   — Computers and office machinery
   — Electronics and telecommunications equipment
   — Electrical machinery and domestic appliances

This taxonomy enables us to study inter-industry differences in process innovations, R&D, innovation output, and sources of and barriers to innovation. In addition, the effects of size can be studied in more detail than in chapter 2.

In empirical studies on taxonomy models, much attention has been paid to the generation and inter-industry flows of embodied and disembodied technological knowledge as represented by process innovations. Though lacking data on direct observations, we may approach this question by studying the introduction of process innovations and the role of R&D.

Table 3.1 reveals that size is an important factor influencing the introduction of process innovations. In all the four sectors, nearly all firms with more than 500 employees reported process innovations. The branch of industry also has an effect; the science-based sector leads in the introduc-

Table 3.1
Units reporting process innovations by size and sector

	N	Producers of traditional consumer goods %	N	Producers of intermediate goods %	N	Specialized suppliers %	N	Science-based firms %
All	**46**	**76.1**	**32**	**78.1**	**91**	**47.3**	**28**	**89.3**
Size								
Small firms	16	75.0	8	75.0	46	37.0	12	83.3
Medium-sized firms	16	62.5	10	70.0	31	41.9	5	80.0
Large firms	14	92.9	14	85.7	14	92.9	11	100.0

tion of process innovations, while the specialized suppliers sector shows the lowest figure.

Table 3.2 shows that **R&D expenditure as a proportion of total innovation expenditure is by far the highest, about 82%, in the science-based sector.** Another result to note is that in small firms with less than 100 employees the proportion of R&D expenditure is smaller than in large firms. (The low value of large firms in the intermediate goods category is due to an exceptional level of investment expenditure. See chapter 2, p. 19.)

Another way to evaluate the role of R&D is to calculate the R&D intensity rate in relation to sales. The figure for science-based firms is 5.1%, for specialized suppliers 3.2%, and for traditional consumer goods and intermediate goods firms about 1%. Size seems to play no role here.

The results above suggest that the large number of units which have introduced process innovations in the traditional consumer goods and intermediate goods sectors, sectors with a rather low level of R&D activity, may to some degree reflect the transfer of technology from specialized suppliers and science-based firms (as exemplified by an engineering company supplying equipment to a textile mill).

One way to assess the organisation of R&D work is to calculate the budget of the central R&D department as a proportion of total R&D expenditure. **The organization of R&D is the most centralised in the science-based sector** and the least centralized in small firms (table 3.3).

As for the output indicators, the results for PPI are ambiguous (table 3.4). As expected, **the proportion of sales generated by the introductory phase is the largest, 11.9%, in the specialized suppliers sector.** Surpris-

Table 3.2
R&D expenditure in proportion to total innovation expenditure by size and sector

	N	Producers of traditional consumer goods %	N	Producers of Firms intermediate goods %	N	Specialized suppliers %	N	Science-based firms %
All	**46**	**40.2**	**30**	**18.2**	**75**	**53.3**	**24**	**82.2**
Size								
Small firms	16	24.5	7	28.5	34	35.0	10	50.9
Medium-sized firms ...	16	38.6	10	28.7	29	54.8	4	70.9
Large firms	14	45.7	13	17.4	12	57.5	10	84.9

Table 3.3
R&D department's share of R&D expenditure by size and sector

	N	Producers of traditional consumer goods %	N	Producers of inter-mediate goods %	N	Specialized suppliers %	N	Science-based firms %
ALL	**38**	**32.1**	**27**	**34.4**	**80**	**40.6**	**23**	**69.2**
Size								
Small firms	14	17.3	7	1.7	37	21.2	9	50.7
Medium-sized firms ...	12	36.3	10	48.6	29	58.1	3	90.0
Large firms	12	57.3	10	48.7	14	69.2	11	82.6

ingly, the figure for the science-based sector is only 2.5%. Even more surprising is the low figure of 1.4% for large science-based firms. But the situation is different for PNP2, i.e. the proportion of sales generated by new products. Again, the figure for the specialized suppliers sector is the highest, 33.9%, but the figure for large science-based firms is also quite high (table 3.5). The lowest value for this indicator is to be found in the traditional consumer goods sector. In all sectors except the traditional consumer goods sector, the proportion of sales generated by product innovations is larger in small and medium-sized firms than in large firms.

Table 3.4
Sales accounted for by products in the introductory phase in the three most important product groups by size and sector

	N	Producers of traditional consumer goods %	N	Pruducers of intermediate goods %	N	Specialized suppliers %	N	Science-based firms %
ALL	**43**	**6.3**	**31**	**4.0**	**65**	**11.8**	**25**	**2.4**
Size								
Small firms	15	2.6	7	6.2	23	13.8	9	5.3
Medium-sized firms	15	2.9	10	1.3	28	7.8	5	12.2
Large firms	13	9.1	14	4.5	14	13.0	11	1.4

Table 3.5
Proportion of sales accounted for by product innovations by size and sector

	N	Producers of traditional consumer goods %	N	Producers of intermediate goods %	N	Specialized suppliers %	N	Science-based firms %
ALL	**38**	**13.3**	**29**	**22.5**	**67**	**33.9**	**24**	**25.1**
Size								
Small firms	13	13.5	8	38.7	32	45.0	9	49.6
Medium-sized firms	12	6.7	8	48.5	23	42.5	4	22.6
Large firms	13	16.7	13	18.4	12	28.5	11	24.4

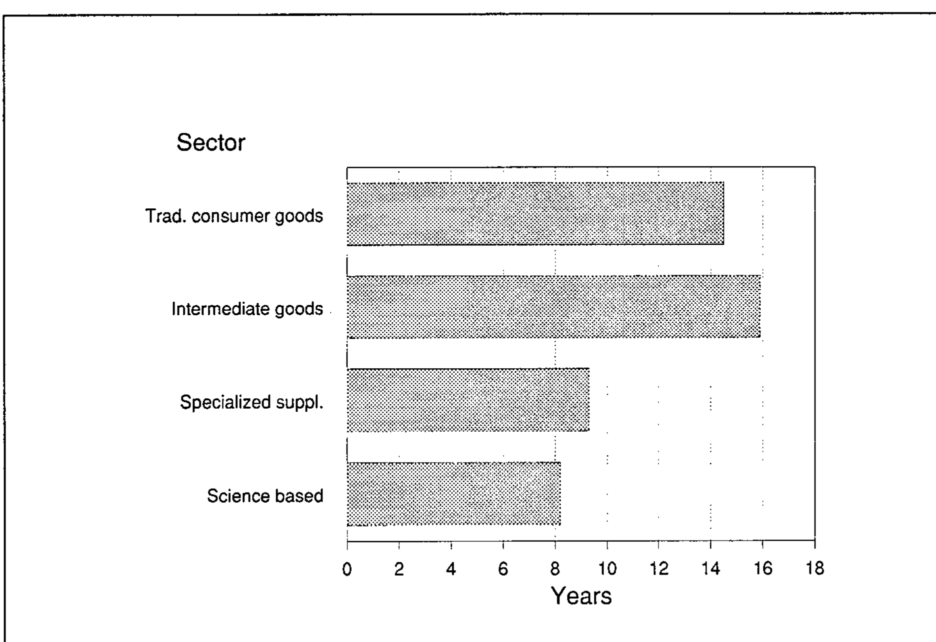
The novelty of innovations can be measured by introductions of products new for the market (considered here as a dummy variable). Table 3.6 shows that **products new for the market are especially common in the science-based and intermediate goods sectors and, to a lesser degree, in the specialized suppliers sector**. Further, large firms are more innovative than small firms when measured by this indicator, a result contradicting the finding for PNP2 above.

Reproduction of the product base can also be described by the average length of the product life cycle. As appears from figure 3.1, our taxonomy breaks down into two groups according to this indicator: **reproduction of products is the fastest in the specialized suppliers and science-based sectors.**

Table 3.6
Proportion of units reporting for the market new products by size and sector

	N	Producers of traditional consumer goods %	N	Producers of Intermediate goods %	N	Specialized suppliers %	N	Science-based firms %
ALL	**46**	**43.5**	**32**	**65.6**	**91**	**58.2**	**28**	**67.9**
Size								
Small firms	16	37.5	8	25.0	46	65.2	12	58.3
Medium-sized firms ...	16	50.0	10	70.0	31	45.2	5	60.0
Large firms	14	42.9	14	85.7	14	64.3	11	81.8

Figure 3.1
Average length of product's life cycle according to sector



Tables 3.7 and 3.8 show the importance of sources of innovation, and of barriers to innovation, in the four taxonomy classes. Although most of the factors differ little from one class to another, some observations may be made. **Production is a more important source of innovation in the traditional consumer goods and intermediate goods sectors than in the other two sectors.** This may reflect the relative importance of "learning by doing" in these sectors. **Further, acquisition of material technology is relatively important to the consumer goods and intermediate goods sectors.** Perhaps surprisingly, co-operation with domestic universities as a source of innovation is of roughly the same importance to all four classes.

Table 3.7
Innovation ideas by sector: Proportions of respondents rating a factor as important

	N	Top management %	Internal R&D %	Marketing %	Production %	Government contracts %	Customer demand %	Fairs, exhibitions %	Competitive situation %
All	**197**	**61.4**	**68.5**	**70.1**	**38.5**	**5.1**	**88.2**	**37.4**	**81.8**
Sector									
Producers of traditional consumer goods	46	75.2	79.2	64.7	50.4	6.8	85.5	55.4	88.5
Producers of intermediate goods	32	53.1	60.4	75.2	51.7	0.0	93.5	27.9	79.9
Specialized suppliers	91	52.8	62.4	71.2	29.5	5.1	90.4	27.2	79.8
Science-based firms	28	65.7	70.2	74.2	22.7	6.4	81.1	37.9	73.7

	N	Acq. of material technol. %	Acq. of immat. technol. %	C-o/w subcontractors %	C-o/w consultants %	C-o/w VTT[1] %	C-o/w domest. univers. %	C-o/w foreign univers. %	C-o/w other firms %	Legislation %
All	**197**	**44.9**	**23.2**	**28.7**	**17.6**	**12.4**	**23.8**	**8.0**	**34.9**	**30.1**
Sector										
Producers of traditional consumer goods	46	58.3	25.4	27.3	27.3	12.6	21.3	8.4	40.6	28.4
Producers of intermediate goods	32	52.6	27.9	26.0	10.6	5.6	24.9	10.3	29.5	31.8
Specialized suppliers	91	32.4	19.7	29.5	16.1	17.3	24.6	5.3	31.3	28.5
Science-based firms	28	42.5	23.6	32.3	6.5	4.7	26.2	12.3	39.4	37.1

1) Technical Research Centre of Finland

Table 3.8
Barriers to innovation by sector: Proportions of respondents rating a factor as important

	N	Risk %	Lack of funding %	Qualitative deficiencies in own R&D %	Lack of qualified personnel %	Lack of information on technology %
ALL	**197**	**51.2**	**35.1**	**44.6**	**46.4**	**30.3**
Sector						
Producers of traditional consumer goods	46	40.6	33.4	55.3	33.4	32.9
Producers of intermediate goods	32	53.0	27.9	37.6	35.3	18.9
Specialised suppliers ...	91	57.5	39.7	39.9	54.4	31.7
Science-based firms ...	28	56.1	33.4	42.1	64.0	32.6

	N	Lack of information on markets %	Resistance towards changes %	Deficiencies in the availability of external services %	Inadequate opportunities for co-operation %	Innovation too easy to use or copy %	Legislation %
ALL	**197**	**36.0**	**27.1**	**10.4**	**8.8**	**33.9**	**23.3**
Sector							
Producers of traditional consumer goods	46	39.6	30.6	8.1	12.2	39.8	29.1
Producers of intermediate goods	32	26.1	28.0	2.3	10.4	44.9	14.9
Specialized suppliers ...	91	39.6	23.6	16.0	6.8	30.8	20.1
Science-based firms ...	28	26.5	28.6	7.4	5.0	16.8	30.0

As for the role of internal R&D, it is interesting to note that although the traditional consumer goods sector gives R&D the highest rating as a source of innovative ideas, the same sector also reports deficiences in the quality of R&D as an important barrier to innovation (table 3.8). As for the other barriers, **lack of market information is a special problem for the specialized suppliers and traditional consumer goods sectors**, while **lack of qualified personnel is a problem for the science-based and specialized suppliers sectors**. The overall risk associated with innovation projects weighs the least in the traditional consumer goods sector. Imitation of the innovations introduced is a smaller problem for the science-based sector than for the three other sectors. This may be due to the high cost of developing innovations or the better protection and secrecy mechanisms in the science-based sector.

To conclude, classification of industries according to the characteristics of their innovation activities seems to be a useful method for analysing the innovation process of the manufacturing industries. Naturally, the taxonomy derived depends on the ingredients selected, i.e. the aspects of the innovation process focused on.

The results of our industrial taxonomy are summarized in table 3.9.

Table 3.9
Summary of taxonomy model

Sector	R&D intensity	Concentration of R&D work	Introduction of process innovations	Sales accounted for by product innovations
Producers of traditional consumer goods	low	low/medium	medium/high	low
Producers of intermediate goods	low	low/medium	medium/high	medium
Specialized suppliers . . .	medium	medium	low	high
Science-based firms	high	high	high	medium

Such industries as food, textiles, wood processing and furniture (i.e. the traditional consumer goods sector) have limited R&D budgets and to some extent depend on process technologies developed by other industries. This is by no means to say that they are somehow inferior to the other sectors. In the economic sense, being "low-tech" may best serve the innovation interests of these industries.

The pulp and paper, clay and stone products, and basic metal industries (i.e. producers of intermediate goods) are also inclined to introduce process innovations, but they tend to develop their technologies internally. For specialized suppliers such as machinery and instrument manufacturers, product innovations are of great importance. Finally, the innovation activities of the chemical and electrotechnical industries are based on systematic, intensive R&D, frequently performed in centralized laboratories.

4. Some comparisons with other countries

4.1 Difficulties in comparing data

Several OECD countries - Germany, the USA, Italy, France, Spain, Austria - have conducted surveys on corporate innovation activities. The surveys have some elements in common, but the questions, definitions and classifications used differ in many respects. Each survey has been developed to meet the respective country's specific national needs.

The first attempt to get comparable data for several countries was made within the framework of the Nordic Innovation Survey described in the introduction to this report. From the very beginning, the survey questionnaire of each country was developed in close association with the other Nordic countries, making it possible to perform many comparisons. All Nordic data in the next section derive from this survey. The results of the survey have been published as a summary report with an Appendix of tables (Nordic Industrial Fund 1991).

The Nordic surveys come perhaps closest to the German survey by the IFO institute and the Italian survey. The IFO institute had the courtesy of supplying some 1988 data according to the Nordic table format. Only some aggregates were available for comparison as the IFO's industrial classification and classification by the size of the unit differ from the Nordic classifications. Some comparisons have also been made with the Italian results based on the national publication (ISTAT 1990). Although many questions in the Italian survey are the same as in the Nordic surveys, comparison is hampered by the different ways of presenting the data. Some US data have been taken from the national publication (Audit & Surveys 1987).

The forthcoming OECD manual for innovation surveys, in the preparation of which the Nordic countries have played a leading role, should improve the conditions for future comparisons. In a few years' time, the OECD will start collecting internationally comparable data on innovation. The EC is likely to follow suit.

For the reasons described above, the comparisons presented in the next section should be treated with caution. Some of the differences may be explained by differences in samples. The Nordic samples were small, ranging from 100 to 200 firms. The US sample of 600 firms was rather small for the size of the country. The German sample size varied from 700 to 1,000, depending on the question. The Italian survey included over 8,000 firms, one-third of which were highly innovative and were asked to supply more detailed data.

Nearly all firms included in the Nordic surveys engage in R&D, while the other surveys also include firms that do not engage in R&D. This will also influence the results.

The results may also be affected by differences in the wording of the questions and in the industrial structure of the countries.

4.2 Some comparisons

Some comparisons have been made concerning most of the aspects of the innovation process discussed in chapter 2: strategies, sources of innovation, barriers to innovation, innovation expenditure, and innovation output

4.2.1 Strategies

Tables 4.1 and 4.2 present product and market strategies and strategies concerning the use of certain inputs.

Table 4.1.
Market and product strategies. proportions of firms regarding the strategy as important

Strategy	Denmark %	Finland %	Norway %	Germany %
Present products Present markets	69	56	81	59
New products Present markets	65	78	67	82
Present products New markets	46	50	55	51
New products New markets	15	45	29	51

Table 4.2.
Strategies concerning selected inputs. proportions of firms regarding the strategy as important

Strategy	Denmark %	Finland %	Norway %	Germany %
More efficient use of inputs	38	82	56	77
New inputs	42	62	34	56
Labour saving	52	66	34	77
Energy saving	17	19	20	34

The most important strategy appears to be to retain the present products on the present markets or to develop new products for the present markets.

German and Finnish firms seem to rate development of new products for new markets somewhat higher than Danish and Norwegian firms do.

More efficient use of the existing inputs such as materials and components is the most important input strategy in Finland and Norway. Labour saving is the most important input strategy in Denmark. The two strategies are rated equally high in Germany.

One-third of German firms regarded energy saving as an important objective. The corresponding figure for Nordic firms was less than one-fifth.

4.2.2 Sources of innovation

In table 4.3, a comparison is made between Nordic and German firms concerning their evaluation of the different sources of innovative ideas.

Innovative ideas from the market are rated the highest in Finland and in Sweden.

Almost 90% of firms in Finland and Sweden regarded customers as their most important source of innovative ideas. In Germany, Denmark and Norway, internal sources like R&D and top management were regarded as relatively more important.

About 80% of firms in Finland and Sweden considered competition to be an important source. The corresponding figure for Germany, Denmark and Norway was 30-40%.

Table 4.3.
Sources of innovation ideas: proportions of firms regarding the source as important

Source	Denmark %	Finland %	Norway %	Sweden %	Germany %
Top management ...	62	61	51	60	40
Internal R&D	55	69	62	70	63
Marketing	41	70	54	61	72
Production	13	39	16	32	42
Customers	54	88	57	86	64
Fairs	30	37	26	26	28
Competition	31	82	30	77	44
Material technology ..	19	45	24	30	19 1)
Immaterial technology	14	23	14	15	
Subcontractors	2	29	9	13	25
Universities	13	24	19	24	13 2)
R&D institutes	14	12	26	..	

1) Acquisition of material and immaterial technology constitutes one category in Germany.
2) Co-operation with universities and R&D institutes constitutes one category in Germany.

In Italy, the most important source of innovation was the acquisition of machinery and equipment. This is at least partly explained by the large proportion of non-R&D firms in the sample. If only highly innovative firms are taken into consideration, R&D and design are as important sources of innovation as acquisition of machinery and equipment.

Besides being caused by differences in the innovation process, the differences between the countries might be explained by differences in industrial structure, the organisation of innovation activities, and the distribution of innovations by type (major innovations, incremental innovations). The same also applies to the barriers to innovation presented in the next section.

4.2.3 Barriers to innovation

The most important barriers to innovation are described in table 4.4.

Risk regarded as too high in relation to expected return is an important barrier to innovation in over half the firms in Nordic countries.

The proportion of firms reporting risk as an important barrier is slightly larger in Germany than in the Nordic countries.

Lack of venture capital as an important barrier to innovation was mentioned more often in Denmark, Finland and Norway (by about one-third of the firms) than in Sweden and Germany.

Lack of qualified labour was an important barrier in about half the firms in Finland and Germany, in one-third of the firms in the other countries.

Lack of information on technology was a problem for one-third of the firms in Finland and Sweden, but for only 6% of the firms in Germany.

Lack of information on markets was an important barrier for between one-third and one half of the firms in all countries.

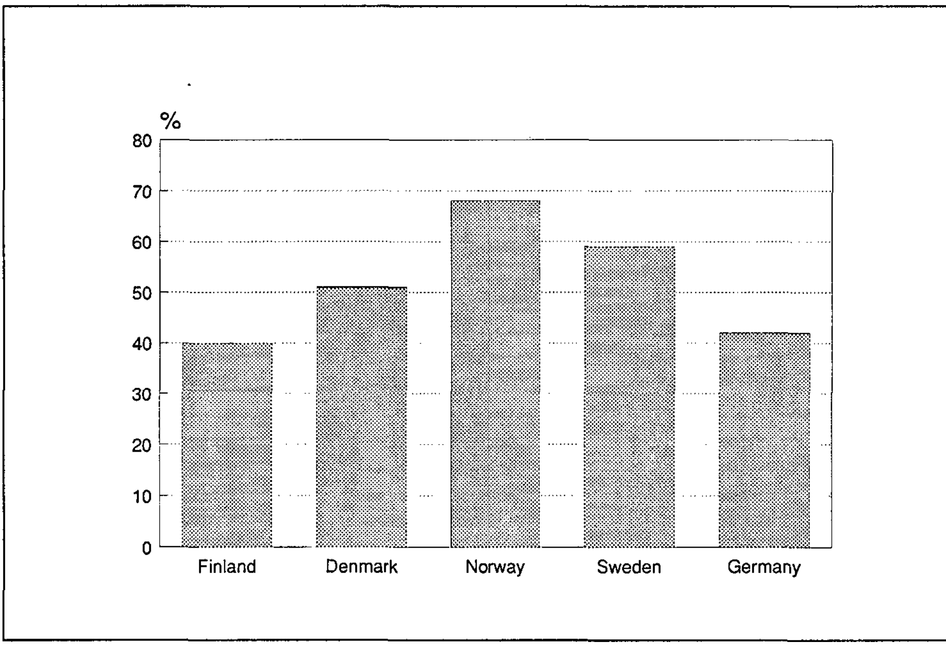
Table 4.4.
Barriers to innovation: proportions of firms regarding the barrier as important

Barrier	Denmark %	Finland %	Norway %	Sweden %	Germany %
Excessive risk	59	51	52	48	72
Lack of venture capital	36	35	38	22	15
Qualitative shortcomings in own R&D	26	45	10	27	39
Lack of qualified personnel	35	46	32	27	47
Lack of information on markets	38	36	27	..	48
Lack of information on technology	..	30	..	33	6
Internal opposition to change	22	27	11	..	10
Innovation too easy to copy	10	34	15	22	..
Legislation	9	23	9	22	20

4.2.4 Innovation expenditure

Innovation expenditure is a difficult issue as very few firms keep a record of this expenditure. In some firms, only information on its distribution between R&D expenditure and other innovation expenditure was available. In Italy and the USA, innovation expenditure refers to the total expenditure incurred in connection with innovations introduced in a given time period; in the other countries, innovation expenditure refers to total expenditure on innovation activities in a given year. Thus, the Italian and US data on innovation expenditure are not directly comparable with the data of the other countries. Therefore, figure 4.1 shows the proportion of R&D expenditure in total innovation expenditure only for the Nordic countries and Germany.

Figure 4.1 R&D expenditure in proportion to total innovation expenditure



Approximately half of total innovation expenditure is accounted for by R&D.

The proportion is about 40% in Germany and Finland and over 50% in Denmark, Norway (68%) and Sweden. The figure for Finland is strongly influenced by the production investments in the pulp and paper industry. If allowance is made for this fact, the figure for Finland would be close to that for the other Nordic countries.

A quick look at the Italian and US figures (which are not directly comparable with the Nordic and German figures) shows that in Italy the proportion of R&D expenditure is as low as 18% for all firms and 21% for highly innovative firms. In Italy, approximately half of the innovation expenditure consists of production investments, which might be explained by the large proportion of firms without internal R&D in the sample. The figure reported for the USA, 39%, is considered to be uncertain.

4.2.5 Innovation output

In figures 4.2 and 4 3, information is provided on two output indicators:

— Proportion of sales generated by products introduced on the market during the past five years

— Proportion of sales generated by products in the introductory phase of the product life cycle

Figure 4.2 Proportion of sales accounted for by product innovations

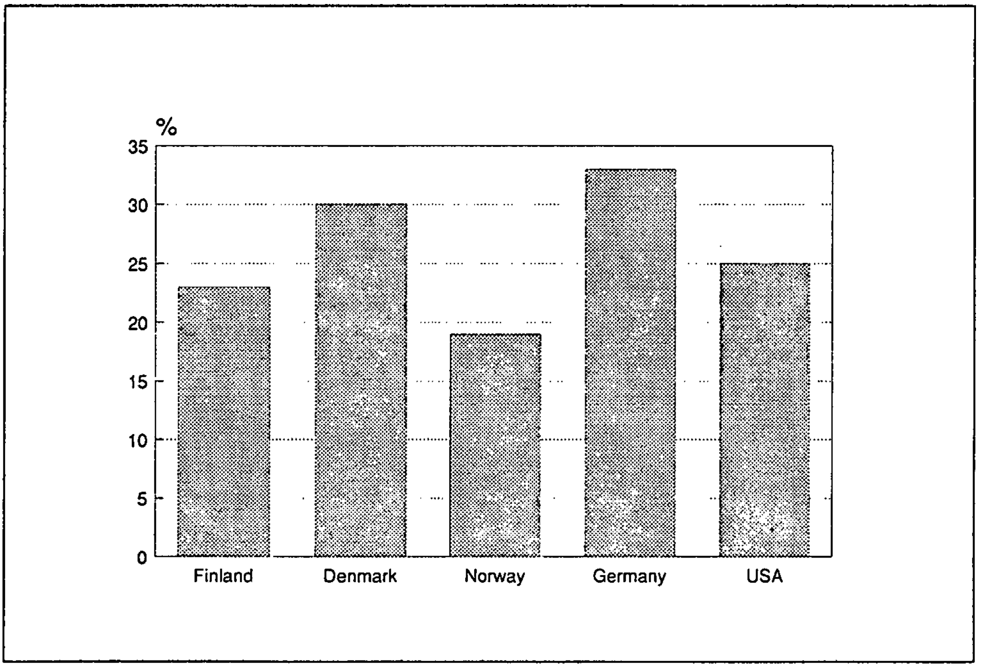
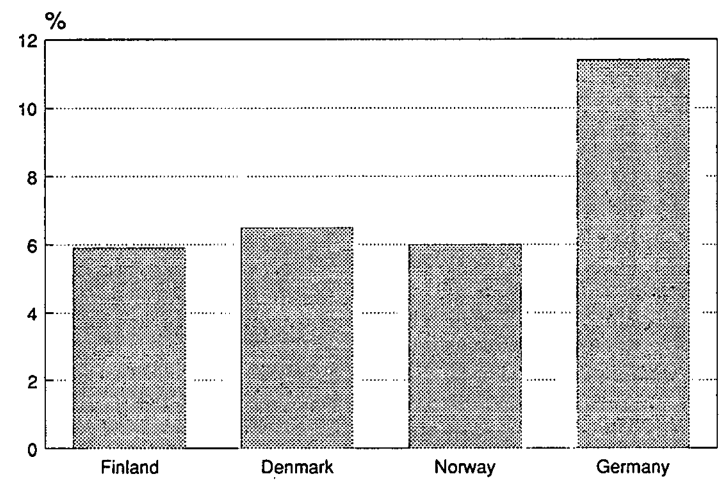


Figure 4.3 Proportion of sales accounted for by products in the introductory phase of life cycle



Germany shows higher values for both indicators than the Nordic countries.

The proportion of sales generated by products in the introductory phase is larger in Germany than in the Nordic countries. In the Nordic countries, the proportion of sales generated by products in the introductory phase is smaller than the corresponding proportion of declining products. In Germany, the proportions are roughly the same. The proportion of products in the growth phase is larger in Finland and Denmark than in the other countries, which to a certain extent mitigates the 'unfavourable' position of these countries with respect to the proportion of products in the introductory phase. The differences may partly be explained by differences in the industry composition of the samples.

The proportion of sales accounted for by product innovations is larger in Germany than in the other countries. This in spite of the fact that the period in question is three years in Germany and five years in the other countries. The figure for the USA seems to be closer to the Nordic level.

In table 4.5, the information on the proportion of sales generated by new products has been broken down by industry. In table 4.6, the information on the proportion of sales generated by products in the introductory phase has been broken down by product group. For this table, comparable information was available only on the Nordic countries; the information on Germany, the USA and Italy is classified according to a different industrial classification.

The difference between the industry classification in table 4.5 and the product group classification in table 4.6 is that the former refers to the main industry of the whole unit and the latter to each of the unit's three most important product groups.

The electronics, computers, and instruments industries show the highest values in all the Nordic countries. This is also a sector with a high R&D intensity rate. Textiles, wearing apparel and furniture also show high values in all the countries despite their low R&D intensity rates.

Table 4.5.
Proportion of sales generated by new products according to industry

Industry	Denmark %	Finland %	Norway %
Food, beverages	15	9	11
Textiles, wearing apparel, furniture	46	39	42
Wood, pulp and paper	17	26	15
Chemicals, chemical products	26	14	11
Basic and fabricated metal	13	15	5
Machinery, transport equipment	38	37	27
Electronics, computers, instruments	58	68	62
Electrical machinery	60	25	27
Other	29	14	10
All industries	**30**	**23**	**19**

Table 4.6.
Proportion of sales generated by products in the introductory phase according to product group

Product group	Denmark %	Finland %	Norway %
Food, beverages	5.2	6.0	7.9
Textiles, wearing apparel	6.9	7.4	5.9
Wood, wood products	0.2	6.7	2.5
Pulp and paper	0.9	3.6	2.8
Publishing	8.0	4.7	..
Furniture, glass	8.6	7.8	10.9
Chemicals, chemical products	9.6	2.7	5.9
Rubber, plastic	1.7	7.9	5.1
Clay and stone products	7.5	2.6	2.4
Basic metal	3.1	5.6	3.8
Fabricated metal products	0.9	9.9	13.0
Special-purpose machinery	7.5	16.6	7.6
General-purpose machinery	4.6	7.9	7.3
Computers, electronics	4.6	0.0	12.2
Electrical machinery	7.0	8.2	4.5
Instruments	16.2	0.0	10.1
Transport equipment	0.8	6.0	6.5
Other	11.7	0.9	2.5
All products	**6.5**	**5.9**	**6.0**

The proportion of sales generated by products in the introductory phase varies in different product groups..

Because of the small samples, it is difficult to draw any conclusions from the differences between the Nordic countries. A very rough analysis of the available German data reveals considerably higher figures for several product groups, such as textiles, wearing apparel, rubber, plastic, electrical machinery, transport equipment, computers and electronics.

5. Conclusions

Our study supports the notion of innovation as a complex process with a number of different characteristics. It has demonstrated that the different relationships existing in the descriptive model described in chapter 1 can be studied empirically with the help of survey data, thus enabling the construction of new indicators relevant to technology policy. The new indicators may facilitate the future development of innovation theory.

The main focus of our study has been on product innovation. There is only a limited amount of information available on process innovation. Since process innovation based on internal R&D or diffused technology is of major importance in a number of industries, it would be useful to have more information available on process innovation and the diffusion of technology.

The characteristics of the innovation process vary from industry to industry. However, there are some features according to which industries can be classified. Our industry taxonomy developed on the basis of the work by Pavitt and by Archibugi et al. was useful in describing the innovation process in Finnish manufacturing. Industry-specific factors such as the role of R&D, the relative importance of product vs. process innovations, sources of innovation, and barriers to innovation are naturally important from the policy point of view.

Ideas for industrial innovations come from a wide variety of sources. Our data confirm the interaction of technology, markets and learning processes as sources of innovation.

The data also give some support to the chain-link model of innovation developed by Kline (1987), in which R&D has a problem solving function and is not a primary source of innovation.

One important aspect of the innovation process is co-operation. Large firms engage in various forms of co-operation (R&D and other) more than small firms do and are more active in trade in technology on both Finnish and international markets. Because of the increasing importance of co-operation, it would be important to improve the conditions of small firms for participating in R&D and other co-operation.

One aim of our innovation survey was to get more information on the role of non-R&D factors in the innovation process. Because of data collection problems, the survey covered only firms that engage in R&D. It would, however, be important to extend innovation surveys to non-R&D firms as well.

For the R&D performing firms, non-R&D-expenditure, including the acquisition of technology and new production capacity, manufacturing start-up, tooling, marketing, etc., turned out to exceed R&D expenditure. As the proportion of non-R&D expenditure varies according to the industry, total innovation expenditure seems to be a better measure of innovation input than R&D expenditure alone. It is thus important to gather information on non-R&D innovation expenditure and to encourage firms to develop their accounting systems so as to make this information more readily available.

The data on innovation output constitute perhaps the most important body of information produced by innovation surveys. Establishing the interconnections of the innovation inputs (R&D and other), innovation outputs and economic performance of firms is very important from the policy point of view. More detailed analysis of the connection between input and output will require time series. Our results suggest that innovation output indicators are closely linked to the firm's main industry and should therefore be analysed in the context of this industry, something that would make inter-industry comparisons very difficult. It will probably be as important to study the development of innovation output indicators as it has been to follow the development of R&D expenditure.

In order to analyse the innovation performance of an individual industry or firm, several output indicators should be used.

Some very rough international comparisons were made as part of this study. Increased international co-operation in the field of technology will increase the need for international comparisons concerning technological development and the role of innovation in different countries in order to improve competitiveness. The forthcoming OECD standard for innovation surveys, in the preparation of which the Nordic countries have played a leading role, will facilitate the making of international comparisons in the future.

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Appendices

APPENDIX 1.
Tables

Appendix table 1A.
Sources of innovation ideas by size of firm.
Proportions of respondents rating a factor as important

	N	Top management %	Internal R&D %	Marketing %	Production %	System for initiatives %	Government contracts %	Customer demand %	Fairs, exhibitions %	Competitive situation %
ALL	**197**	**61.4**	**68.5**	**70.1**	**38.5**	**13.1**	**5.1**	**88.2**	**37.4**	**81.8**
Size										
Small R&D intensive firms ...	27	60.0	69.2	57.7	19.2	17.4	21.7	88.5	19.2	50.0
Small firms	55	68.1	64.3	69.0	43.6	14.0	5.0	85.2	41.9	84.2
Medium-sized firms	62	59.1	70.4	71.1	41.0	6.6	3.4	89.9	36.3	85.2
Large firms	53	52.2	73.1	76.0	32.7	20.0	1.5	91.0	38.3	85.0

	N	Acquisition of material technology %	Acquisition of immaterial technology %	C-o with subcontractors %	C-o with consultants %	C-o with VTT[1)] %	C-o with domestic universities %	C-o with foreign universities %	C-o with other firms %	Regulations, legislation %
ALL	**197**	**44.9**	**23.2**	**28.7**	**17.6**	**12.4**	**23.8**	**8.0**	**34.9**	**30.1**
Size										
Small R&D intensive firms ...	27	32.0	4.0	30.8	20.0	12.0	28.0	9.1	30.8	16.7
Small firms	55	51.8	28.7	34.3	18.0	15.2	23.9	9.0	29.6	29.3
Medium-sized firms	62	42.7	20.5	15.0	22.9	5.7	17.8	2.1	39.8	29.6
Large firms	53	40.3	24.7	38.8	7.5	18.1	31.7	14.5	39.3	37.8

1) Technical Research Centre of Finland

Appendix table 1B.
Sources of innovation ideas by R&D intensity.
Proportions of respondents rating a factor as important

	N	Top management %	Internal R&D %	Marketing %	Production %	Government contracts %	Customer demand %	Fairs, exhibitions %	Competitive situation %
ALL	**197**	**61.4**	**68.5**	**70.1**	**38.5**	**5.1**	**88.2**	**37.4**	**81.8**
R&D intensity									
High R&D intensity	62	64.7	66.4	73.1	20.4	9.1	92.6	41.8	65.4
Medium R&D intensity	75	56.2	72.3	75.8	34.6	5.5	86.3	28.4	84.8
Low R&D intensity	60	64.8	66.0	61.8	55.6	1.8	87.1	44.1	90.0

	N	Acquisition of material technology %	Acquisition of immaterial technology %	C-o with subcontractors %	C-o with consultants %	C-o with VTT[1)] %	C-o with domestic universities %	C-o with foreign universities %	C-o with other firms %	Regulations legislation %
ALL	**197**	**44.9**	**23.2**	**28.7**	**17.6**	**12.4**	**23.8**	**8.0**	**34.9**	**30.1**
R&D intensity										
High R&D intensity	62	21.6	13.3	26.8	21.9	13.8	34.0	9.4	32.8	22.9
Medium R&D intensity	75	50.8	32.3	26.8	7.0	8.3	13.3	9.5	38.4	26.9
Low R&D intensity	60	53.9	20.2	31.9	26.2	15.7	28.1	5.3	32.7	38.6

1) Technical Research Centre of Finland

Appendix table 1C.
Sources of innovation ideas by degree of export orientation.
Proportions of respondents rating a factor as important

	N	Top management %	Internal R&D %	Marketing %	Production %	Government contracts %	Customer demand %	Fairs, exhibitions %	Competitive situation %
ALL	**197**	**61.4**	**68.5**	**70.1**	**38.5**	**5.1**	**88.2**	**37.4**	**81.8**
Proportion of exports									
No export	34	80.6	72.7	57.9	65.0	4.6	90.6	48.5	85.9
Less than 25%	66	63.0	68.9	79.4	33.1	5.0	86.1	25.7	76.1
25% - 50%	39	63.6	68.9	65.5	34.7	11.3	82.9	45.4	84.2
Over 50%	58	40.9	64.1	69.5	27.4	1.4	92.9	40.0	85.1

	N	Acquisition of material technology %	Acquisition of immaterial technology %	C-o with subcontractors %	C-o with consultants %	C-o with VTT[1] %	C-o with domestic universities %	C-o with foreign universities %	C-o with other firms %	Regulations, legislation %
ALL	**197**	**44.9**	**23.2**	**28.7**	**17.6**	**12.4**	**23.8**	**8.0**	**34.9**	**30.1**
Proportion of exports										
No export	34	54.5	30.4	28.6	25.9	13.0	31.8	10.6	35.9	37.1
Less than 25%	66	44.0	18.5	37.1	18.8	15.1	16.0	4.5	39.1	27.3
25% - 50%	39	49.9	31.2	21.3	17.0	13.7	31.4	12.3	27.1	24.2
Over 50%	58	34.6	18.4	21.6	9.1	7.2	23.2	8.0	33.5	32.8

1) Technical Research Centre of Finland

Appendix table 2A.
Barriers to innovation by size of firm.
Proportions of respondents rating a factor as important

	N	Risk %	Lack of funding %	Qualitative deficiencies in own R&D %	Lack of qualified personnel %	Lack of information on technology %
ALL	**197**	**51.2**	**35.1**	**44.6**	**46.4**	**30.3**
Size						
Small R&D intensive firms	27	56.0	65.4	30.8	46.2	42.3
Small firms	55	48.8	31.7	42.2	50.4	32.6
Medium-sized firms ..	62	48.6	32.5	52.2	43.1	28.9
Large firms	53	58.2	32.8	42.5	43.8	22.9

	N	Lack of information on markets %	Resistance towards changes %	Deficiancy in the availability of external services %	Inadequate oppor-tunities for co-operation %	Innovation too easy to use or copy %	Regulations, legislation %
ALL	**197**	**36.0**	**27.1**	**10.4**	**8.8**	**33.9**	**23.3**
Size							
Small R&D intensive firms	27	57.7	15.4	32.0	20.0	44.0	16.7
Small firms	55	23.0	30.1	9.3	4.8	36.7	20.3
Medium-sized firms ..	62	41.3	25.5	6.0	7.3	32.8	22.0
Large firms	53	43.3	28.8	11.0	14.2	25.8	34.0

Appendix table 2B.
Barriers to innovation by R&D intensity.
Proportions of respondents rating a factor as important

	N	Risk %	Lack of funding %	Qualitative deficiencies in own R&D %	Lack of qualified personnel %	Lack of information on technology %
ALL	**197**	**51.2**	**35.1**	**44.6**	**46.4**	**30.3**
R&D intensity						
High R&D intensity ..	62	47.5	44.3	35.5	52.5	35.0
Medium R&D intensity	75	53.1	34.0	56.6	51.6	29.1
Low R&D intensity ...	60	51.8	29.8	37.9	36.3	28.4

	N	Lack of information on markets %	Resistance towards changes %	Deficiencies in the availability of external services %	Inadequate oppor-tunities for co-operation %	Innovation too easy to use or copy %	Regulations, legislation %
ALL	**197**	**36.0**	**27.1**	**10.4**	**8.8**	**33.9**	**23.3**
R&D intensity							
High R&D intensity ..	62	39.4	19.8	24.9	9.5	33.5	20.3
Medium R&D intensity	75	47.8	32.6	5.0	7.7	26.5	20.3
Low R&D intensity ...	60	20.7	26.1	6.2	9.5	42.2	28.8

Appendix table 2C.
Barriers to innovation by degree of export orientation.
Proportions of respondents rating a factor as important

	N	Risk %	Lack of funding %	Qualitative deficiencies in own R&D %	Lack of qualified personnel %	Lack of information on technology %
ALL	**197**	**51.2**	**35.1**	**44.6**	**46.4**	**30.3**
Proportion of exports						
No export	34	53.9	35.2	46.7	54.8	36.4
Less than 25% ...	66	47.0	34.5	46.7	45.7	26.1
25% - 50%	39	53.7	35.0	54.8	38.8	32.1
Over 50%	58	53.7	36.1	32.6	45.6	30.1

	N	Lack of information on markets %	Resistance towards changes %	Deficiencies in the availabiity of external services %	Inadequate oppor-tunities for co-operation %	Innovation too easy to use or copy %	Regulations, legislation %
ALL	**197**	**36.0**	**27.1**	**10.4**	**8.8**	**33.9**	**23.3**
Proportion of exports							
No export	34	32.4	49.2	10.5	7.2	48.4	36.4
Less than 25% ...	66	29.8	19.2	9.3	12.0	24.2	20.8
25% - 50%	39	40.7	22.0	13.7	7.8	48.3	17.5
Over 50%	58	44.7	23.5	9.7	6.1	25.8	20.5

Appendix table 3.
Acquisition and sale of technology

All	N	Purchased from Finland %	Purchased from other countries %	Sold to Finland %	Sold to other countries %
Type of technology					
Patents	197	7.2	3.8	0.9	0.9
Licences	197	4.4	6.1	1.2	7.3
Technological consulting services	197	35.9	9.0	3.2	3.5
Means of production containing new technology	197	24.3	28.7	0.9	2.3
Raw materials and intermediate goods containing new technology.	197	19.0	14.7	1.6	2.5
Information systems containing new technology	197	22.1	9.6	0.6	0.6
Firms for the purpose of acquiring or selling technology	197	6.8	2.0	0.5	0.9
Other	197	0.0	0.0	0.0	0.0

R&D intensive small firms	N	Purchased from Finland %	Purchased from other countries %	Sold to Finland %	Sold to other countries %
Type of technology					
Patents	27	0.0	0.0	0.0	0.0
Licences	27	3.7	0.0	3.7	0.0
Technological consulting services	27	14.8	3.7	7.4	0.0
Means of production containing new technology	27	11.1	7.4	3.7	0.0
Raw materials and intermediate good containig new technology	27	7.4	11.1	11.1	3.7
Information systems containing new technology	27	3.7	0.0	0.0	0.0
Firms for the purpose of acquiring or selling technology	27	3.7	0.0	0.0	0.0
Other	27	0.0	0.0	0.0	0.0

Small firms	N	Purchased from Finland %	Purchased from other countries %	Sold to Finland %	Sold to other countries %
Type of technology					
Patents	55	6.0	1.5	0.0	0.0
Licences	55	2.3	2.3	0.7	9.8
Technological consulting services	55	28.2	0.7	0.0	2.3
Means of production containing new technology	55	11.9	18.0	0.0	0.0
Raw materials and intermediate goods containing new technology	55	14.0	4.4	0.0	2.9
Information systems containing new technology	55	10.2	6.7	0.7	0.7
Firms for the purpose of acquiring or selling technology	55	2.9	0.0	0.6	0.0
Other	55	0.0	0.0	0.0	0.0

Medium-sized firms	N	Purchased from Finland %	Purchased from other countries %	Sold to Finland %	Sold to other countiries %
Type of technology					
Patents	62	4.6	1.8	0.0	0.0
Licences	62	4.3	4.5	0.9	1.8
Technological consulting services	62	37.8	6.0	2.3	2.7
Means of production containing new technology	62	30.9	34.5	0.0	0.0
Raw materials and intermediate goods containing new technology	62	22.2	22.7	0.9	0.0
Information systems containing new technology	62	24.8	11.6	0.0	0.0
Firms for the purpose of acquiring or selling technology.	62	7.3	0.0	0.9	0.0
Other	62	0.0	0.0	0.0	0.0

Large firms	N	Purchased from Finland %	Purchased from other countries %	Sold to Finland %	Sold to other countries %
Type of technology					
Patents	53	17.0	13.5	4.5	4.5
Licences	53	9.0	19.4	1.5	14.9
Technological consulting services	53	57.6	32.9	9.0	8.9
Means of production containing new technology	53	44.3	49.9	3.0	11.9
Raw materials and intermediate goods containing new technology	53	28.9	23.9	1.5	5.3
Information systems containing new technology	53	49.9	16.4	1.5	1.5
Firms for the purpose of acquiring or selling technology	53	14.9	10.4	0.0	4.5
Other	53	0.0	0.0	0.0	0.0

Appendix table 4A.
Distribution of sales across the phases of product life cycle by industry

	N	Introduction %	Growth %	Saturation %	Decline %
ALL	**188**	**5.9**	**35.9**	**49.5**	**8.7**
Industry					
Food, beverage and tobacco	17	6.0	30.6	51.2	12.2
Textiles, wearing apparel, furniture	16	7.7	50.5	29.2	12.6
Wood, pulp and paper	22	3.9	42.8	46.1	7.2
Chemicals and chemical products	9	2.5	28.2	60.4	8.9
Basic and fabricated metal	20	5.1	26.4	63.1	5.5
Machinery and equipment	45	14.3	36.3	38.2	11.2
Electronics, electrical machinery	28	2.7	39.6	48.3	9.4
Transport equipment	18	6.3	52.9	37.5	3.3
Other manufacture	13	4.8	22.2	60.5	12.5

Appendix table 4B.
Product innovations in proportion to the total product base by industry

	N	Proportion of product innovations %
ALL	**165**	**42.1**
Industry		
Food, beverage and tobacco	17	26.9
Textiles, wearing apparel furniture	16	45.7
Wood, pulp and paper	22	33.7
Chemicals and chemical products	8	38.1
Basic and fabricated metal	17	29.4
Machinery and equipment	37	50.3
Electronics, electrical machinery	20	61.3
Transport equipment	15	56.8
Other manufacture	13	31.3

Appendix table 4C.
Proportion of sales and exports accounted for by product innovations by industry

	N	Proportion of sales %	N	Proportion of exports %
ALL	**142**	**22.6**	**110**	**23.0**
Industry				
Food, beverage and tobacco	14	8.6	9	9.4
Textiles, wearing apparel, furniture	14	38.8	11	28.8
Wood, pulp and paper	20	26.2	17	22.7
Chemicals and chemical products	9	13.6	7	19.0
Basic and fabricated metal	12	14.7	9	15.1
Machinery and equipment	34	36.4	30	34.3
Electronics, electrical machinery	16	44.9	12	47.3
Transport equipment	12	36.6	11	30.5
Other manufacture	11	13.9	4	7.2

Appendix table 5A.
Distribution of sales across the phases of product life cycle by size of firm

	N	Introduction %	Growth %	Saturation %	Decline %
ALL	**188**	**5.9**	**35.9**	**49.5**	**8.7**
Size					
Small R&D intensive firms	24	37.1	34.4	21.8	6.7
Small firms	54	7.8	40.6	46.2	5.5
Medium-sized firms	58	3.9	25.7	62.1	8.3
Large firms	52	6.3	38.3	46.3	9.1

Appendix table 5B.
Product innovations in proportion to the total product base by size of firm

	N	Proportion of product innovations %
ALL	**165**	**42.1**
Size		
Small R&D intensive firms	15	64.0
Small firms	50	41.2
Medium-sized firms	52	39.3
Large firms	48	41.5

Appendix table 5C.
Proportion of sales and exports accounted for by product innovations by size of firm

	N	Proportion of sales %	N	Proportion of exports %
ALL	**158**	**22.6**	**116**	**23.0**
Size				
Small R&D intensive firms	16	62.9	6	66.5
Small firms	46	32.5	30	39.5
Medium-sized firms	47	28.5	36	29.8
Large firms	49	20.6	44	21.9

Appendix table 6A.
Distribution of sales across the phases of product life cycle by degree of export orientation

	N	Introduction %	Growth %	Saturation %	Decline %
ALL	**188**	**5.9**	**35.9**	**49.5**	**8.7**
Proportion of exports					
No export	29	1.6	14.5	81.7	2.2
Less than 25%	64	6.8	39.2	47.3	6.7
25% - 50%	39	6.3	31.8	47.5	14.4
Over 50%	56	5.9	38.9	47.6	7.6

Appendix table 6B.
Product innovations in proportion to the total product base by degree of export orientation

	N	Proportion of product innovations %
ALL	**165**	**42.1**
Proportion of exports		
No export	25	34.2
Less than 25%	57	43.3
25% - 50%	34	40.6
Over 50%	49	45.9

Appendix table 6C.
Proportion of sales and exports accounted for by product innovations by degree of export orientation

	N	Proportion of sales %	N	Proportion of exports %
ALL	**142**	**22.6**	**110**	**23.0**
Proportion of exports				
No export	14	7.4	0	–
Less than 25%	56	36.2	44	39.1
25% - 50%	27	13.7	24	16.2
Over 50%	45	23.5	42	23.7

APPENDIX 2
The survey and the population

The point of departure in planning the sample was to obtain data on industrial companies according to whether they pursue research and development (R&D) or not. Units pursuing R&D were classified by size, and a special category designated as R&D-intensive small firms was formed. The resulting classification was as follows:

1. Large R&D firms (sales in excess of FIM 200 million);

2. Small and medium-sized R&D firms (sales FIM 10-200 million);

3. R&D-intensive small firms (minimum sales FIM 0.1 million; R&D expenditure as a percentage of sales in excess of 10%; at least one person engaged in R&D work);

4. Non-R&D firms (minimum sales FIM 10 million).

The population of each of the groups 1-3 was drawn from the R&D statistics compiled by the Central Statistical Office of Finland (CSO), which in principle cover all units pursuing R&D. The population of group 4 was obtained by excluding from the data of the CSO's Enterprise Register all firms that, according to the official CSO statistics, pursued R&D.

The sampling ratio was 1:2 for group 1, 1:3 for group 2, and 1:2 for group 3. From group 4, a sample of approx. 150 units was drawn, with the relative frequencies of the different industries the same as in the sample drawn from groups 1-3.

A total of 377 questionnaires were sent out in May 1989. The information requested concerned mainly the year 1988, for some questions the years from 1984 to 1988. A firm/concern or a subdivision of a firm/concern was the statistical unit.

A second questionnaire was sent to all firms that did not respond to the first questionnaire. Furthermore, most firms that failed to supply data were contacted by telephone. Data collection was finished by October 1989.

Typical reasons for non-response were lack of time/resources or, simply, lack of interest. Some firms (particularly in printing and publishing) considered the questions as not applicable to their business.

The proportion of acceptable responses was 58% (or 205 units); the figures do not include units that had gone out of business or had merged with another unit. The response rates of the different groups are presented in table 1. below:

Table 1.
Response rates according to sample group

	Sample	Respondents	Response rate
Total	**355**	**205**	**58**
Large firms with own R&D	66	53	80
Small or medium-sized firms with own R&D	128	76	59
R&D-intensive small firms	38	27	71
Firms without own R&D	123	49	40

It turned out that 78% of the respondents in group 4 reported R&D (although at a modest level). This may be due to several reasons, e.g.:

— Failure of R&D statistics to cover the whole of the population pursuing R&D;

— Biased responding probability, non-R&D units being uninterested to participate in an innovation survey;

— Problems in excluding R&D firms from group 4.

Further, it should be noted that the periodic R&D survey gives exact definitions of research and experimental development. The innovation survey gave only brief definitions of the items to be included in R&D expenditure.

Non-R&D firms may regard innovation activity as irrelevant. In addition, the structure of the questionnaire turned out to be unsatisfactory from the point of view of some non-R&D firms.

An example of problems in excluding R&D firms from group 4 is provided by a concern which is treated as one unit in R&D statistics, but whose operations span more than one industry and which may consist of several more or less independent subsidiary companies. Because of identification problems, a unit in a concern like this is liable to be classified as a non-R&D firm. This was not, however, a significant problem in our survey; only six units belonging in groups 1-3 were discovered among the respondents in group 4.

The respondents in sample groups 1-3 reported R&D expenditures worth FIM 1,133 million, accounting for about 25% of the estimated industrial R&D expenditure in 1988. In addition, FIM 37.3 million was spent on intramural R&D in group 4.

Only units pursuing R&D were therefore included into this survey. The few respondents reporting that they did not engage in R&D were excluded. The final number of acceptable responses thus came to 197. Table 2. shows the distribution of respondents according to size and industry.

Small R&D-intensive firms (sample group 3) form a separate category because they were thought likely - due to certain intrinsic characteristics - to behave differently from the firms in the other groups.

Table 2.
Distribution of data according to size of firm and industry

	All	Small R&D intensive firms	Small firms	Medium-sized firms	Large firms
All	**197**	**27**	**55**	**62**	**53**
Industry					
Food, beverages and tobacco	18	.	5	6	7
Textiles, wearing apparel, furniture	17	1	5	9	2
Wood, pulp and paper	22	.	6	5	11
Chemicals and chemical products	9	.	2	2	5
Basic and fabricated metal	23	7	6	5	5
Machinery and transport equipment	65	8	20	25	12
Electronics, computers and instruments	16	10	1	2	3
Electrical machinery and equipment	13	1	6	2	4
Other manufacture	14	.	4	6	4

4

Both weighted and unweighted data are used. Weighted data are used in descriptive tables, while factor analysis and calculation of correlations are based on unweighted data.

The weights of each group are calculated according to the principles of stratified random sampling. Applying the method to groups 1-3 was straightforward enough: the weights were determined from the responses in proportion to the population of each group.

As for group 4, more effort was needed because of the lack of information about the coverage of R&D statistics. A sample of 20 firms was drawn from among those firms in group 4 that did not respond to the original survey. The 20 firms were sent a questionnaire asking whether they pursued systematic R&D or not. The results of this supplementary survey were then used to calculate the weights of the units in group 4. However, because of the low frequencies, especially at the industry level, some subjective judgments had to be made, resulting in lower weights than indicated by the empirical results.

Appendix 3
Factor analysis on ideas of innovation

Our analysis produces three factors. The variance explained by these three factors is 41.5%. Below are factors and their structure.

Rotated factor pattern (varimax rotation)

Factor 1.
Scientific and technological co-operation (variance explained 15.8%)

Variable	Loadings
Co-operation with domestic universities	.82
Co-operation with foreign universities	.77
Co-operation with Technical Research Centre of Finland	.68
Co-operation with consultants	.58
Acquisition of immaterial technology	.52
Co-operation with subcontractors	.40
Co-operation with other firms	.39
Legislation, standards, regulations	.29
Internal R&D	.23
Acquisition of material technology	.14
Government contracts	.14
Fairs, exhibitions, meetings	.13
Top management	.09
Production	.08
Marketing	.03
System for initiatives	.03
Competitive situation	.00
Customer demand	-.02

Factor 2.
Ideas from the arragement of production (variance explained 14.1%)

Variable	Loadings
Production	.77
System for initiatives	.68
Acquisition of material technology	.66
Top management	.52
Government contracts	.51
Co-operation with subcontractors	.34
Co-operation with Technical Research Centre of Finland	.30
Co-operation with consultants	.26
Legislation, standards, regulations	.25
Acquisition of immaterial technology	.24
Fairs, exhibitions, meetings	.24
Marketing	.17
Internal R&D	.06
Competitive situation	.03
Co-operation with domestic universities	-.01
Co-operation with other firms	-.02
Customer demand	-.12
Co-operation with foreign universities	-.19

Factor 3.
Ideas from market (variance explained 11.6%)

Variable	Loadings
Customer demand	.71
Marketing	.69
Fairs, exhibitions, meetings	.52
Co-operation with other firms	.46
Legislation, standards, regulations	.44
Competitive situation	.39
Internal R&D	.32
Production	.21
Government contracts	.20
Co-operation with domestic universities	.17
Co-operation with foreign universities	.16
Co-operation with subcontractors	.13
Co-operation with Technical Research Centre of Finland	.10
Acquisition of material technology	.04
System for initiatives	.02
Co-operation with consultants	.02
Top management	-.01
Acquisition of immaterial technology	-.01

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Kindly return the questionnaire before **30 June 1989**

Innovation activities of Industry

General information

This questionnaire collects data on the foundations, scope, results and effects of the innovation activities of industrial companies.

The information should mainly be supplied at the company level. If more convenient, it may also be supplied separatively for individual units of the company. The data of concerns may be supplied by divisions comprising several companies.

The information is requested primarily on units operating in Finland. However, if units operating abroad play an important role in the innovation activities of units operating in Finland, the answer may also contain information on these units.

Some questions may not be equally appropriate to all units. If exact information is not available, an informed estimate may be supplied instead. Should this be impossible or meaningless from the point of view of the company or unit, the question may be left unanswered.

All information supplied should relate to the unit specified on page 2. Under statutory provisions concerning the Central Statistical Office of Finland, the data supplied are confidential and will only be used for statistical purposes. No information at the company level will be released to a third party.

Concepts and definitions

Innovation activities introduce something essentially new to a company's activities. This questionnaire collects information on product innovations (new or substantially improved old products) and on process innovations (new methods of production).

A product innovation refers to a product whose intended use, performance characteristics, technical properties, or materials and components use differ from the unit's previous products to the extent that it can be considered to be a new or essentially improved old product. A product innovation may include several incremental innovations relating to different components of the product. Product innovations may be based on R&D activities or on technology acquired by other means.

Products made to the customer's order (unit production) are not counted as product innovations unless they embody a significant R&D effort on the part of the company or otherwise represent major changes in the product's performance characteristics or field of application. Aesthetic (design based) innovations are not counted as innovations in this survey.

A process innovation refers to the adoption of new production methods. The methods may be intended for producing new or essentially improved goods or for essentially increasing the production efficiency of existing goods. Process innovations are based on R&D activities or on acquired technologies. Acquisition of new types of machine or equipment (but not the mere replacement of old models or extension of existing processes) can also be counted as process innovations.

Rationalisation of office routines, related acquistion of machinery and equipment included, is not counted as innovation.

TK 444.10a

General background information

Name of unit	Address of unit

Name and position of contact person	Telephone number of contact person

Turnover of unit in 1988	Exports of unit in 1988	Number of employees in unit at year's end 1988
FIM million	FIM million	

Type of unit	Yes	No
Concern		
Parent company of concern		
Subsidiary company of concern		
Division of concern		
Other independent company		
Other (Please, specify)		

Mode of production	Yes	No
Serial production		
Unit production		
Process industry		

Does the answer include units operating abroard		

1. Information on the unit's most important product groups

Questions 1.1-1.6 deal with the unit's three most important product groups. The product groups may be defined according to the unit's own terminology, and data may be supplied only for one or two groups if so desired.

1.1 The most important product groups in proportion to turnover in 1988 (Please provide definitions of the product groups)

	Proportion of turnover %
Product group A :	
Product group B :	
Product group C :	

1.2 Country of biggest competitor in the most important product groups in 1988

	Market of Finland	Market of Nordic countries	Market of Western Europe	World market
Product group A				
Product group B				
Product group C				

If the competitor is Finnish, then Finland should be specified.
If there is no competition in the product group write no as an answer.

1.3 Expected growth in demand in the most important product groups over the next five years

Demand is expected to	Product group		
	A (x)	B (x)	C (x)
Increase			
Remain unchanged			
Decrease			

1.4 Unit's market shares for the most important product groups in 1988

	Market of Finland, total (%)	Market of Nordic countries, total (%)	Market of Western Europe, total (%)	World market, total (%)
Product group A				
Product group B				
Product group C				

1.5 Distribution of turnover for the most important product groups by phase of life cycle of products in 1988

	Product group		
	A (%)	B (%)	C (%)
Introductory phase			
Growth			
Saturation			
Decline			
Total	100	100	100

1.6 Estimated average duration of innovation projects and length of life cycles of products in the most important product groups

	Product group		
	A	B	C
Duration of innovation project (in years)			
Life cycle of product (in years)			

2.The foundations and the scope of innovation activities

2.1 Development strategies

For an evaluation of the unit's general development strategy, please indicate he importance of selected basic development alternatives for your unit according to the following scale:

0 = no information or impossible to evaluate **4 = important**
1 = not at all important **5 = crucial**
2 = sligthly important
3 = rather important

Encircle the relevant alternative

	No inform.	Not important				crucial
Development strategies in relation to products and markets						
Present products, present markets	0	1	2	3	4	5
New products, present markets	0	1	2	3	4	5
Present products, new markets	0	1	2	3	4	5
New products, new markets	0	1	2	3	4	5
Development strategies in relation to technology						
Development of new technology for the industry	0	1	2	3	4	5
Further development of technology developed by others	0	1	2	3	4	5
Utilization of technology developed by others	0	1	2	3	4	5
Improvement of company's existing technology	0	1	2	3	4	5
Development strategies in relation to the use of inputs of production						
Use of new inputs	0	1	2	3	4	5
More efficient use of existing inputs	0	1	2	3	4	5
Energy conservation	0	1	2	3	4	5
Labour cuts	0	1	2	3	4	5

2.2 Innovative ideas

Impulses for innovation projects may come from many different sources. Please evaluate the importance of the following factors (scale as above):

Encircle the relevant alternative

	No inform.	Not important				crucial
Internal impulses						
Top management	0	1	2	3	4	5
Internal R&D	0	1	2	3	4	5
Marketing	0	1	2	3	4	5
Production	0	1	2	3	4	5
System for initiatives	0	1	2	3	4	5
Impulses from markets						
Government contracts	0	1	2	3	4	5
Customer demand	0	1	2	3	4	5
Fairs, exhibitions, meetings	0	1	2	3	4	5
Competitive situation	0	1	2	3	4	5
Other external impulses						
Acquisition of material technology (e. g. machinery, equipment)	0	1	2	3	4	5
Acquisition of immaterial technology (licenses,information systems,know-how)	0	1	2	3	4	5
Co-operation with subcontractors	0	1	2	3	4	5
Co-operation with consultants	0	1	2	3	4	5
Co-operation with the Technical Research Centre of Finland	0	1	2	3	4	5
Co-operation with domestic universities and research institutes	0	1	2	3	4	5
Co-operation with foreign universities and research institutes	0	1	2	3	4	5
Co-operation with other companies (units)	0	1	2	3	4	5
Legislation, standards, regulations	0	1	2	3	4	5

2.3 Factors contributing to innovation activity

Several factors do contribute to the success of innovation projects. We ask you to evaluate the weight of the following factors according to the scale bellow:

0 = no information or impossible to evaluate **4 = important**
1 = not important at all **5 = crucial**
2 = sligthly important
3 = rather important

Encircle the relevant alternative

	No inform.	Not important				crucial
Internal factors						
Contributions of top management	0	1	2	3	4	5
Co-operation of R&D with marketing and production	0	1	2	3	4	5
Company's information service	0	1	2	3	4	5
External factors						
Use of technical services (testing, standardization, patenting)	0	1	2	3	4	5
Use of other advisory services (e. g. marketing, management)	0	1	2	3	4	5
Co-operation with subcontractors	0	1	2	3	4	5
Co-operation with the Technical Research Centre of Finland	0	1	2	3	4	5
Co-operation with other domestic research institutes	0	1	2	3	4	5
Co-operation with domestic universities	0	1	2	3	4	5
Co-operation with vocational institutes	0	1	2	3	4	5
Co-operation with foreign universities and research institutes	0	1	2	3	4	5
Co-operation with other companies (units)	0	1	2	3	4	5

2.4 Barriers to innovation activities

There are a number of factors which may hamper the launching and implementation of innovation projects. Please evaluate the importance of such factors according to the same scale scale as above in 2.3:

Encircle the relevant alternativ

	No inform.	Not important				crucial
Economic factors						
Risk related to innovation too big	0	1	2	3	4	5
Lack of funding	0	1	2	3	4	5
Own innovation potential						
Qualitative deficiencies in own R&D	0	1	2	3	4	5
Lack of qualified personnel	0	1	2	3	4	5
Lack of information on technology	0	1	2	3	4	5
Lack of information on markets	0	1	2	3	4	5
Resistance towards changes in company	0	1	2	3	4	5
Deficiencies in the availability of external services	0	1	2	3	4	5
Inadequate opportunities for co-operation	0	1	2	3	4	5
Others:						
Innovation too easy to use or copy	0	1	2	3	4	5
Regulations, legislation	0	1	2	3	4	5

2.5 Total cost of innovation activities in 1988

	FIM, millions	FIM, millions
Total costs of research and development in unit		
Intramural R&D		
Extramural R&D		
Total costs of other innovation activities		
Acquisition of technology		
Application of innovations		
Marketing of innovations		
Acquisition of new production capacity		
Total cost of innovation activities		

The aim of this question is to get a rough idea of the size of the unit's innovation expenditure. Accurate data derived from the unit's accounts are not necessary. If practicable, the data supplied should be broken down by subgroups of R&D expenditure and other innovation expenditure. Otherwise, enter the totals of R&D expenditure and other innovation expenditure.

Intramural R&D expenditure consist of current and capital costs for R&D undertaken by unit's own personnel, regardless of whether the activities have resulted in innovations or not.

Extramural R&D expenditure consist of acquisition costs for R&D services.

Expenditure for the acquisition of technology consist of patent and licence costs, i.e. administrative and legal costs related to patenting and licencing, and of other costs for the acquisition of external know-how.

The expenditure for the application of innovations covers the launching of the production of a new article or of an essentially improved existing article and the implementation of a new production process. Included are such costs as post-R&D product design, trial production as part of launching the production, tooling, education and organisational development.

The marketing expenditure of innovations covers market research, advertising campaings and trial marketing.

The acquisition of new production capacity covers machinery and equipment incorporating new technology and the acquisition of machinery, equipment and new buildings as part of the application of the innovation.

3. Results of innovation activities and their utilization

3.1 Product and process innovations in 1984-1988 and total number of products in 1988 (see "Conceps and Definitions" page 1)

	All products, total	Product group		
		A	B	C
Total number of products at year's end 1988				
Product innovations or new and substantially improved old products introduced on the market 1984 – 1988				
– of which: products not produced before by other companies				

	Yes	No
Has the unit applied new production processes or methods in 1984 – 1988		
If the answer is yes, how many?		

To ensure comparability, the data for 1984-1988 should be supplied according to the unit's organisational structure as of 1988.

In calculating the number of products, products should be differentiated by such criteria as target group, field of application, and essentially altered technical or other characteristic. Versions of the same product differing in size or colour are not counted as different products.

Product innovations can be defined on the basis of R&D projects that have resulted in marketable new products or in essential improvements in existing products. Thus, improvements in different parts of the same product are not counted as separate innovations.

Companies engaged in unit production may calculate the number of all products turned out within the given period of time unless the product base at year's end 1988 allows some other reasonable mode of definition. Correspondingly, product innovations may be defined as products turned out during the given period of time and which incorporate an essential amount of R&D.

In the space bellow, give a brief description of the method you have used in calculating product and process innovations

Criteria for calculating the innovations:

3.2 Unit's evaluation of the commercial success of new products or substantial product improvements introduced on the market during 1984-1988

	Total	Product group A	Product group B	Product group C
Success				
Failure				
Neither				
Too early to evaluate				
Total				

The figures for totals should be at least as great as nuber of product innovations in 1984-1988 as reported in section 3.1

3.3 New products and substantial improvements of old products in proportion to turnover and exports in 1988

Please tick the relevant alternative

%	Proportion of turnover (x)	Proportion of exports (x)
0 — 10		
11 — 20		
21 — 30		
31 — 40		
41 — 50		
51 — 60		
61 — 70		
71 — 80		
81 — 90		
91 — 100		
Impossible to estimate		

4. Research and development and purchase and sale of technology

	Yes	No
Has the unit engaged in internal R&D in the 1988?		

If the answer is yes, please respond to questions **4.1 – 4.3**

If the answer is **no**, you may proceed to item **4.4**

4.1 R&D projects in progress at year's end 1988 by estimated duration

Duration	Number of projects
A year or less	
Over a year, two years at most	
Over two years, five years at most	
Over five years	
Total	

4.2 Information on internal R&D activities in 1988

	Yes	No
Has the unit a separate R&D department or some other comparable unit providing services for the unit		
If yes, what is its share of the internal R&D expenditure	%	
Has the unit participated in national or international technology programs in 1988	Yes	No
Please tick the relevant program	(x)	
National technology programs of the Technological Development Centre		
Technology programs of the Nordic countries		
Eureka		
EC Programs		
ESA		
COST		
Scientific and technological co-operation with the CMEA-countries		

4.3 The relation of research and development to certain new technologies in 1988

Tick the relevant alternative

	Aim of unit's R&D	
	Development of new technics (x)	Application of new technics (x)
Information technology Microelectronics		
Materials in electronics		
Optoelectronics		
Computer technology		
Information systems, software		
Artificial intelligence, expert systems		
Data transfer technology		
Automation and control technology		
Biotechnics Enzymes		
Fermentation		
Gene technology		
Diagnostics		
Materials New steel materials		
Light metals		
Powder metallurgy		
Ceramics		
Composites		
Polymers		
New surface materials		
Supra conductors		

4.4 R&D contracts funded by the unit in 1988

Please tick the type(s) of institution with which the unit has signed a research contract.

	Domestic (x)	Foreign (x)
Other companies (or units) in the same concern		
Other industrial companies		
Consulting and service firms		
Inventors		
Technical Research Centre of Finland		
Other public research institutes		
Private research institutes		
Vocational institutions		
Universities		

4.5 Research co-operation of the unit in 1988

Please tick the relevant types of institution in different country groups.

	Finland (x)	Other Nordic countries (x)	EC 1) (x)	USA (x)	Japan (x)	CMEA (x)	Other (x)
Other companies (units) in the same concern							
Other industrial companies							
Consulting and service firms							
Inventors							
Technical Research Centre of Finland							
Other public research institutes							
Private research institutes							
Vocational institutions							
Universities							

1) Excluding Denmark

Research co-operation comprises joint R&D projects with other institutions and own projects formally linked to the projects of other institutions.

4.6 Purchase (acquisition) and sale of technology in 1988

Tick the relevant alternative

	Purchased in		Sold to	
	Finland	Other countries	Finland	Other countries
Patents				
Licences				
Technological consulting services				
Means of production or processes containing new technology				
Raw materials and intermediate goods containing new technology				
Information systems containing new technology				
Companies or parts of companies for the purpose of acquiring or selling technolgy				
Other (please specify)				

Comments concerning the data supplied and ideas and opinions related to the questions:

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184. **Ari Leppälahti – Mikael Åkerblom,** Industrial Innovation in Finland. August 1991. 82 pp.

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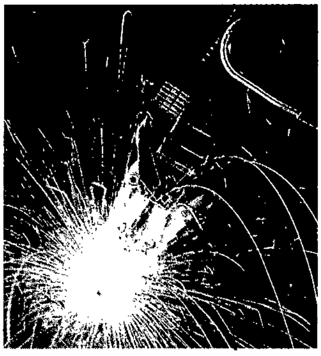

This report deals with an empirical study on the innovation activities of Finnish manufacturing industries. The topics covered include the determinants, the process and the outcome of innovation activities. As a new method of evaluating technological development, statistical indicators of industrial innovation are constructed and tested.

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