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Innovations and the Success of Firms

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Foreword

This report is one of the in-depth studies carried out within the Sfinno project of Finnish innovations. The report is based on the Sfinno innovation database, undertaken in VTT Group for Technology Studies.

The general theme of this report is to analyse the economic effects of innovations. The report focuses on the dynamic impact of innovations on the success of firms. We examine the innovation activity in Finland in the so-called Rothwell's "System Integration and Networking" (SIN) framework. Empirically, this is related to the object approach in innovation studies, since information on individual innovations is needed. We use Sfinno survey data on Finnish innovations in the last decade and financial data to analyse the SIN model in the structure-performance framework.

We are indebted to our Sfinno team members - Tanja Tanayama, Jukka Hyvönen and Tuomo Pentikäinen - at the VTT Group for Technology Studies for their valuable help. The authors also wish to thank Soile Kuitunen and Terttu Luukkonen for their comments on the manuscript. The discussion with Eija Ahola, Aija Leiponen and other members of the supervising group have been most beneficial. Our thanks also go to Katharine Wakelin for her comments. Finally, we would like to thank the National Technology Agency (Tekes) for their financial support. The responsibility for any errors falls on the authors.

Espoo, November 2000

Petri Niininen Jani Saarinen

Executive Summary

This report provides some new results concerning the relationship between innovation and the success of firms. The objective of this report is to study the innovative process and its effect on profitability. Using empirical data on innovations, we analyse how the various characteristics of Rothwell's "System Integration and Networking" (SIN) model correspond to innovations commercialised in Finland in the last decade. Specifically, we examine how the system integration model of the innovative process can account for the profitability of a firm.

The report is divided into two different sections. In the first section, the theoretical framework is developed. This framework builds on the ideas of the innovation process in Rothwell's SIN model. We have quantified five different variables suggested by the SIN model and analysed them by using the Sfinno data. These five variables include: 1) strong linkages with (leading) customers; 2) strategic linkages with primary suppliers (vertical linkages); 3) horizontal linkages; 4) product design combining the old with the new; and 5) speed of development.

On the basis of the empirical literature in Finland and abroad, the premises of the SIN model are broadly supported. Also, the evidence from the Sfinno survey is in line with the model. As results from the Sfinno survey suggest, the most important partners in developing an innovation are customers (1). In the case of vertical linkages (2), subcontractors are regarded as the second most important collaboration partner, right after the customers. In horizontal linkages (3), however, the results were rather interesting. According to Sfinno, the role of foreign competitors was seen as being more important than domestic ones. However, the importance of both factors has been growing over the studied period. In the fourth case (4), the wheel has not been reinvented - not the whole wheel at any rate. This is due to the fact that 40% of the innovations have required knowledge about the combination of different components and modules. Finally, the time from development to commercialisation (5) has been analysed. When comparing the time of development in the 1980s and 1990s, the results suggest a decrease from 2.5 years to 2.0 years. This means that the development cycle of innovations has shortened quite remarkably.

In the second part of this paper, we examine more thoroughly whether the properties of the SIN model are linked to profits in the firms. The results suggest

that the key features set forth in the SIN model are supported by the empirical analysis. The role of customers and suppliers in the development process has a clear effect on profitability. Customer involvement is more important for smaller firms, while supplier relationship matter more for firms in general. Reducing the average time from commercialisation to break-even by six months increases profits by about ten per cent. Innovations which are new on the world market do not seem to generate profits automatically, while a granted patent appears to have a strong effect on profitability. The complexity of an innovation has a profitability effect in general, but this tends to disappear among smaller firms.

All in all, the characteristics of the innovation process are more important than the properties of an innovation. The features described in the SIN model by Rothwell seem to affect the profits of the firm positively. The same applies to the quality of an innovation in terms of patents and the use of new technologies in the development process. Finally, there does not seem to be just one knowledge base that improves the innovation process.

Table of Contents

List of Figures and Tables

1 Introduction

In the new growth theory, innovative activity is the engine of economic growth. Innovative activity is captured by the Solow residual, i.e. technological change. Technological change is the most important factor of economic growth in developed economies: new technologies explain at least half of the economic growth, maybe even three quarters (Tassey 1997). Technological change is driven by innovations. At the firm level, a constant flow of innovations is required to maintain competitiveness and organic growth.

In this paper, we attempt to shed light on the innovative process and its effect on the profitability of firms. The report is divided into two different sections. In the first section, the theoretical framework is developed. The framework builds on the ideas of the innovation process model by Rothwell (1992a), called the "System Integration and Networking" (SIN) model. We quantify five different variables of this model and analyse them by using the Sfinno data. In the second part of this study, we examine more thoroughly whether the properties of the SIN model are linked to profits in the firms. Using empirical data on innovations, we analyse how the various characteristics of Rothwell's model of the innovation process correspond to innovations commercialised in Finland in the last decade. Specifically, we examine how the system integration model of the innovative process can account for the profitability of a firm.

The study is based on Finnish Innovations – “Sfinno” – which is a project started by the Group for Technology Studies in the Technical Research Centre of Finland (VTT) in 1997 (please see Appendix 1 or Palmberg *et al.* (2000) for a detailed description). The aim of this project is to provide a deeper and more comprehensive understanding of the industrial renewal process in Finland from the point of view of individual innovations. Innovation has been defined as *an invention which has been commercialised on the market by a business firm or equivalent.* The Group for Technology Studies has constructed a database that contains basic data on about 1500 innovations commercialised during the 1980s and 1990s in Finland. Innovations are identified through expert opinion, systematic reviews in technical journals and annual reports of a number of selected large companies.

An important part of the database for this paper is the survey. Innovations in the data were linked to the innovators in firms. Subsequently, innovators were contacted and data were gathered by survey, company registers and patent data.

The additional data consists of information on the industrial and technological field of innovations, the year of commercialisation and the company, as well as the origin and diffusion of innovations, R&D collaboration, public support and the commercial significance of the innovations. The Sfinno database consists basically of product innovations.

Given the shortcomings of the traditional proxies, the economic significance of innovations has also been studied by measuring the actual innovative output. Using proxies such as R&D expenditure or patent indicators is referred to as the subject approach in the innovation literature. The idea in the subject approach is to identify potential firms that might be innovative. In the alternative object approach, actual innovations are studied. This can be achieved, for instance, by counting new product launches or innovations meeting a certain criterion, such as a granted patent.

The differences in economic performance between innovative and non-innovative firms have been well documented. Differences in exports, sales growth and profitability between firms with innovations and those without have been studied. Innovations and profitability have been studied, for example, using the SPRU innovation data. According to the work of Geroski (1993), the number of innovations produced by a firm has a positive effect on its profitability. In his study of UK manufacturing firms during the period 1972-83, Geroski found that the market shares of innovators were nearly six times larger than those of non-innovators. However, the difference in profits between innovators and non-innovators was not fixed throughout the sample period.

Leiponen (2000a) analysed the impact of a firm's competencies and innovation on profitability in the Community Innovation Survey (CIS) data. Innovations did not always have a positive effect on profitability; e.g. product innovations tended to have adverse effects on profits. It seems that competencies such as the education of employees described the capabilities of the firm equally well as the innovation variables. Also, the determinants of profitability were different for innovators and non-innovators. Leiponen concludes that a more detailed understanding of the innovative process is needed in order to understand the mechanism linking capabilities and profits.

In other CIS data-related studies, discussions about the differences between innovating and non-innovating firms have been developed further. Bartoloni &

Baussola's study about profitability and innovation in Italy suggests that innovating firms generate (on average) operating profits which are 9 per cent higher than those of non-innovating firms. Klomp and Van Leeuwen (1999) found similar results in their study of the importance of innovation in the Netherlands. They observed a significantly positive effect of the level of innovation output on sales growth, considering the period 1994-96 (CIS-2).

However, the innovative process itself remains a black box in the subject approach. This is often the case in object approach studies, too. Innovations differ in novelty, complexity and usage, they can be process related, services or products, and the intellectual property rights vary, depending on the properties of the innovation. Counting innovations is often like comparing apples to oranges. As expected, we know that new products generate new sales and exports. What is less well known is the mechanism and properties of the innovations that bring about new business opportunities. In the terms of Kline & Rosenberg (1986), the throughput or the innovative process within the firm still remains vague.

2 Theoretical Framework

2.1 Chain-Linked Model

In 1986, Kline & Rosenberg presented an integrated model of the innovation process, called the "chain-linked model". The biggest difference between this new model and the former ones was that there is not just one major path of activity in the innovation process. Innovation can take many different routes. The first path of innovation is called the “central chain of innovation”, beginning with a design and continuing through development and production to marketing. During this process, multiple sources of knowledge are used. Research and technological development tends to be interwoven, and side-links to research all along the central chain of innovation are used.

The second path is a series of feedback links that connect and co-ordinate R&D with production and marketing. Feedback links are seen as a part of the co-operation between product specification, product development and marketing. These links play a crucial role in the chain-linked model. Because of these multiple possibilities of the innovation process, innovation is difficult to measure using this model.

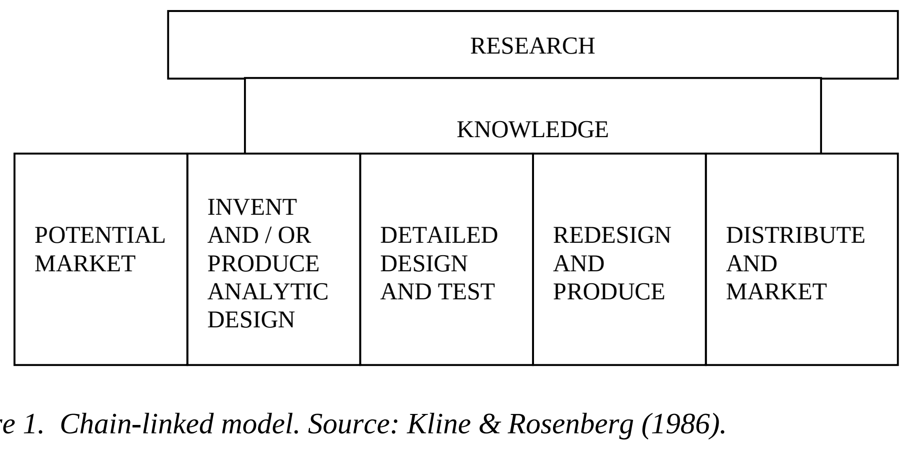

Figure 1. Chain-linked model. Source: Kline & Rosenberg (1986).

Kline & Rosenberg introduced their model in the mid-1980s, and it achieved wide popularity among innovation and R&D researchers as well as practitioners who dealt with these subjects. Naturally, the model was an illustration of an innovation process, describing the situation in general in the companies during that time. What has happened since then is a great increase in R&D spending. In Finland, the high level of investment in R&D started already in the late 1970s. During the eighties, investments increased continuously, achieving a phase of extremely rapid growth in the mid-1990s. Among other factors, these investments have in many ways affected the nature of the innovation process inside companies.

To begin with, while investment in R&D has expanded, the number of R&D personnel has increased rapidly. More resources are directed at the development of new products in order to introduce some successful products to the markets. While competition has increased, the importance of new successful products has become more essential for companies' survival. According to one rule of thumb from the real world, today's *companies can survive only two product failures in a row*. If more, the risk of bankruptcy is almost unavoidable. Because of these threats, more attention has been paid to the innovation process itself.

What can be noticed about this process is that the development time of innovations has shortened in recent decades. In R&D-oriented companies, especially pharmaceuticals and IT-based companies, the innovative process has become a "forward-moving" process. Characteristic of this process is that companies usually have no time for backward links. At the same time, the nature of collaboration has changed towards a more systematic and organised "team-game", where different actors are exchanging ideas during the development process of innovation. In the beginning of this process, there is a large number of different ideas. The total number of them is cut down by means of different evaluation operations. This means also that when one specific idea does not qualify to get through an evaluation stage, it is abandoned.

In order to describe this process by means of the number of ideas and the decrease in them during the *entire* development process, a closer look at this process might be worthwhile. In the following figure, the mortality curve of new product ideas is illustrated in general.

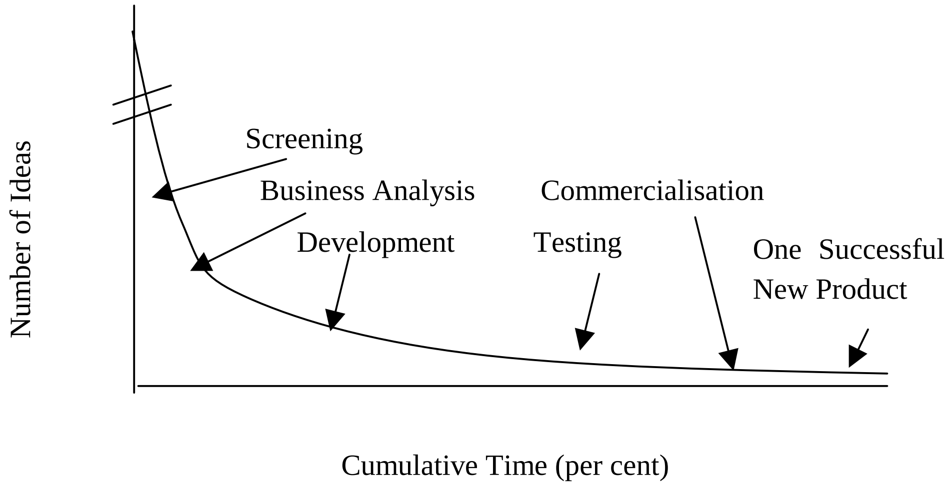

Figure 2. Mortality curve of new product ideas.

(The original idea, the so called "Development Funnel" was introduced by Wheelwright & Clark, 1992. p. 112)

As can be seen in the figure above, a large number of ideas exist at the beginning of a new innovation process. Firstly, evaluation and screening processes drastically reduce the number of ideas. Before the beginning of the development phase, the number of ideas is further reduced by some business analysis. The process so far is crucial in two respects. Firstly, successful ideas have to be found already in the early stage of the innovation process. Secondly, as the development process starts, things become extremely costly. Because of these, the number of ideas carried forward to the development stage has to be limited to those most likely to succeed.

2.2 System Integration and Networking Model

In order to measure the innovation process by means of all the different actors affecting it, a new model had to be found. Roy Rothwell (1992a) has made some major efforts by developing a new method of measuring different aspects of the innovation process. This model is called the "System Integration and Networking" (SIN) model. This is the newest model in the literature describing the innovative process. It represents a somewhat idealised development of the integrated model (chain-linked model), but with added features, e.g. much closer strategic integration between collaborating companies. It also represents a model of the future in which conceptualisation leads practice. Due to the fact that this model is still under development, the number of studies has been quite limited. However, the most important feature of this model is that it gives us an empirically operational framework to measure different aspects of the development process of innovation - the throughput stage - which has not been as easy to measure with some older models.

The following list introduces some of the features which are considered and measured in this study. It is worth remembering that the entire description of SIN made by Rothwell describes more than 20 different features. The entire list and explanations can be found in Appendix 2. Due to the characteristics of these features, some of them cannot be quantified at all. Fortunately, the most important ones can be measured in Sfinno. These features are:

1) Involving leading-edge users;

2) Close linkages with primary suppliers;

3) Assessing external know-how;

4) Product design combining the old with the new; and

5) Time-based strategy.

It is notable that not all of these five features can be found in the model by Kline and Rosenberg. In their model, the innovation process happens mainly in-house, while in Rothwell's model, information from above is used on a large scale. Also the fifth point, the time-based strategy, did not have much place in Kline and Rosenberg's model. As mentioned before, the so-called feedback links were essential in that model. In Rothwell's model, however, there is not much time for any backward steps during the innovation process.

2.3 Implementation of Rothwell's model

Below we discuss these variables in the context of the empirical literature both in Finland and abroad. The objective of this section is to give the reader some empirical results from abroad, and also to introduce the Sfinno data in the light of these features. The Sfinno survey data presented in this section is taken directly from the database, while in chapter 4, the relationship with profitability is measured in greater detail with the aid of econometrics.

1) Strong linkages with (leading) customers:

An important feature of this model is that it brings the users into the development process. Technologically competent users who demand innovation can assist in increasing the speed of development and reducing development costs, especially if they become actively involved in the product development. A comparative study of technical developments in the U.K. and West German machine tool industries illustrates some major differences in customers' participation in the development process. In the West German companies, customer involvement in the product design and development process was seen as axiomatic if the company wanted to be successful. In the British companies, customers were not involved in the development process until the product was on the market. These differences helped the West German machine tool suppliers to become more successful than their British competitors (Parkinson 1982, see also Rothwell 1977).

Rothwell (1992a) has introduced a list of the main characteristics of the so-called "leading-edge customers". According to him, these customers are early adopters on the diffusion curve; they have a proven track record in the successful use of innovative products; they establish forward-looking, innovation-demanding specifications for new product purchases; they become actively involved in suppliers' developments; and they are a primary source of post-launch improvements.

In Sfinno, the overwhelming majority of the innovations have been developed in some kind of collaboration, irrespective of industry. In the Sfinno questionnaire, the respondents were asked whether or not collaboration had taken place at any stage in the innovation's development process. Respondents were also asked to assess the importance of partners, if collaboration had taken place. As the results from Sfinno suggest, customers are the most important partners in developing an innovation. In more than 50 per cent of all cases, the role of customers was seen as the most important in developing an innovation (Palmberg *et al*. 2000: 36) Surprisingly, no variations can be observed in the three five-year sub-periods of the study. Year after year the importance of customers has kept its stable position and in comparison with other collaborative partners exceeded them by a wide margin.

Two other interesting observations can be made from the Sfinno data. Firstly, in the case of the overall importance of different collaborative partners for those innovations that involved collaboration, about two thirds of the respondents regarded domestic customers as being important or very important in the development of innovations. The role of foreign customers was perceived as being of relatively less importance. However, the Sfinno does not give us any hints about the entry of customers to the development process.

Secondly, there are some differences in the case of the importance of collaborative partners across firm size groups. In the case of companies with fewer than ten employees, some 49 per cent of them considered collaboration with customers as being important, while in companies with 10-99 employees, the corresponding proportion was 66 per cent.[1] Thereafter, the importance of collaboration diminishes as the firm size grows (Palmberg *et al*. 2000: Fig. 6, p. 37).

2) Strategic linkages with primary suppliers: (vertical linkages)

Close and early linkages with suppliers can reduce development costs and increase development speed. These linkages include, for instance, co-development of new products. Japanese companies have been particularly successful in adopting this feature of product development. As early as the 1970s, the collaboration of leading Japanese vehicle companies with their own robotics suppliers and similar collaboration with electronic companies in the same groups was an important factor behind their success (Freeman, 1988). Today, this new feature appears to be occurring increasingly in Europe and the USA with the emergence of true supplier-manufacturer partnerships (Lamming, 1992).

In the Finnish study of collaborative R&D in 34 companies of the engineering and electronic industries (Halme *et al*. 1999), the role of subcontractors in the "key" development projects of the companies were found to be the most important in comparison with other models of collaborative R&D. Above all, the role of subcontractors was of special importance during the mid-part of the project, while the role of customers dominated at the beginning of the process.

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[1] = Number of respondents who considered the role of customers to be important or very important.

Considering the importance of subcontractors in the development process of innovation, the results from Sfinno are quite interesting. Overall, subcontractors are regarded as the second most important collaboration partner. About one third of the respondents found domestic subcontractors to be important or very important, while 18 per cent perceived foreign subcontractors as being important. One possible explanation for this phenomenon could be that firms appropriate the most important external knowledge inputs to innovation from domestic customers, subcontractors etc, while more peripheral knowledge comes from foreign sources. This suggests that domestic networks still dominate despite globalisation and rapidly increasing R&D investments abroad (Palmberg *et al*. 2000: 39, 62).

When studying the changes in the importance of collaborative partners over time, the results indicate that the relative importance of subcontractors is increasing slightly: 22 per cent in 1985-89 compared with 28 per cent[2] in 1995-98. Besides subcontractors, only VTT has been so successful in continuously increasing its status as an important collaborative partner over the studied period. This can be seen as an interesting indicator explaining the changes that are taking place in the development processes of innovations in Finnish companies.

3) Horizontal linkages:

As many results of the innovation studies show, innovation today has become significantly more of a networking process. During the 1980s the number of horizontal strategic alliances and collaborative R&D consortia with competitors has increased rapidly (Lemola, 1994; Lievonen, 1998). Companies have realised that the use of external R&D can speed up new product development, as can buying or licensing-in existing technology (Gold, 1987). Another form of linkage is the so-called "technology programme", which has become more popular among companies. This happened especially during the 1990s, when the strategic role of the National Technology Agency as a co-ordinator and financier increased.

The effectiveness of horizontal linkages, especially collaborative R&D, has been discussed widely. Mowery (1998) has identified some potential benefits of R&D collaboration for industrial firms. These benefits include the ability of member

[2] = Number of respondents who considered the role of subcontractors to be important or very important.

firms to capture "knowledge spillovers" that otherwise are lost, and less duplication of R&D investments among member firms. Some negative effects can be found in the study of Pavitt (2000). According to Pavitt, instead of technology-related costs being reduced, both corporate R&D costs and their dispersion across fields have continued to increase in large firms.

The empirical findings from Sfinno cover a wide range of information about the horizontal linkages in Finland. To start with the importance of domestic competitors as collaborative partners in the development of innovation, only four per cent of the respondents regarded them as important or very important. This result is somehow interesting, considering that foreign competitors achieved an eight per cent level of importance. It should be noted also that the importance of all competitors, both domestic and foreign, has been growing (from five per cent to seven per cent) over the observation period. The low level of importance as a whole gives weak support to the horizontal linkage argument in Rothwell's model of the innovation process.

The role of technology programmes was important. Overall, there was programme-based collaboration in 25 per cent of the innovations. Approximately 80 per cent of these programmes were National Technology Agency (Tekes) programmes. The following figure illustrates the share of innovations involving programme-based collaboration. It is worth remembering that the increase in the number of these programmes might be explained by their late entry. The first programmes were launched in 1984, and since then, their number has increased continuously. In line with the increase in the number of programmes, the R&D funding from Tekes rose from EUR 49 million in 1985 to EUR 410 million in 1999 (Source: Statistics Finland).

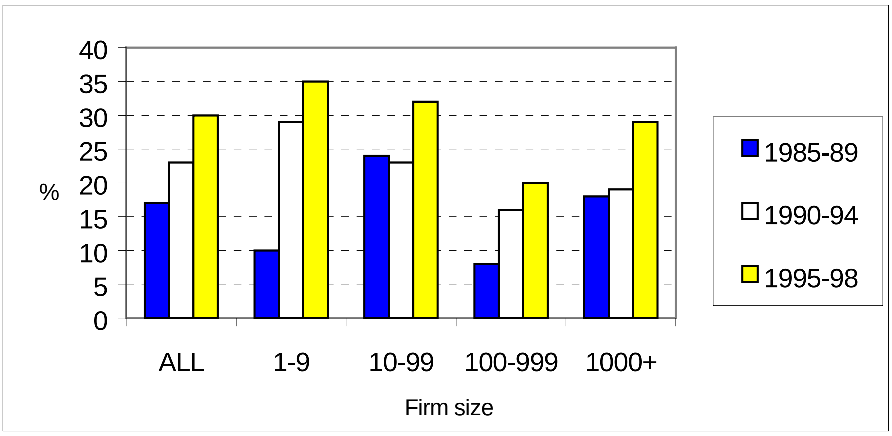

Figure 3. Share of innovations involving a technology programme during collaboration across the firm size groups.

As can be noticed from the figure above, the overall participation in technology programmes to develop innovations has increased continuously. In particular, the growth has been rapid in the case of companies with 1-9 employees: from 10 per cent to 35 per cent. Firms participating in a technology programme are likely to co-operate with other firms from the same technology area. Some of these firms are competitors. The low figures for collaboration with other firms can be partly explained by the fact that the co-operation occurs in a technology programme. Either way, this supports the idea of the SIN model

4) Product design combining the old with the new: Do not reinvent the wheel!

Product design combining the old with the new relates to the use of major elements of existing designs as the basis for creating new product types, rather than new models of existing types. Nowadays, companies are increasingly outsourcing their R&D activities by collaborating and buying solutions. Each company has its own core competence, which gives it an advantage on the market. In cases where other companies are developing new products, it might be worth considering buying these already existing competencies, instead of developing them on your own. By doing so, companies are able to shorten the development time of new products and to avoid possible failures during the development process. Another feature of today's R&D is the focus on the so-called "derivative projects" as a means of shortening the development time.

In order to measure this feature of Finnish innovations, respondents were asked to identify the nature of knowledge input that was required for the development of innovations. Five different features were offered, and the respondents were asked to pick only one alternative. These alternatives included commercialisation of core technology, combination of different components or modules, process technology, service concepts, and other types of knowledge. The distinction between different types of knowledge is not straightforward since it is unclear how these different alternatives should be interpreted (Palmberg *et al*. 2000: 24) Despite these reservations, there were some differences across industries and firm sizes.

Overall, 40 per cent of the innovations required knowledge about the combination of different components or modules. This supports the fourth feature of the SIN-model that cautioned not to reinvent the wheel. The use of elements of existing designs as the basis for creating some new product types seems to be a common phenomenon in the development of innovations in Finland. The commercialisation of core technology was an important type of knowledge in 35 per cent of the cases, and achieved second place in this comparison.

Studying the results across industries reveals some major differences. In electricity, gas & water supply, for instance, the combination of different components and modules achieved a share of 83 per cent. In the cases of foodstuffs, textiles & clothing, and oil & chemicals products, the share varied between 14 and 22 per cent. These examples attest to the different characteristics of the development process of innovations in Finnish industries.

5) Speed of development:

Finally, perhaps the most important feature or result of Rothwell's model of the innovation process is the speed of development. As can be read from the four other features above, their objective is to shorten the development time (innovation cycle). Those features can also be considered as pre-conditions for changes in the development time. Achievement of these pre-conditions may usually lead to decreases in the development time automatically. However, the importance of being a fast innovator puts the company managers in a new situation. Given the scope of activities that needs to be addressed in order to accelerate product development, being a fast innovator must be at the forefront of corporate strategy (Rothwell, 1994).

Lately, the importance of being a fast innovator has emerged as an important factor for corporate strategic consideration, and a number of companies have begun to adopt explicit time-based strategies. It has been noticed that a company that develops high-quality products rapidly has several options that it may pursue. Firstly, it may start a new product development project at the same time as its competitors, but introduce the product to the market much sooner. Alternatively, it may delay the beginning of a new development project in order to acquire better information about market developments etc, introducing its product at the same time as its competitors but bringing to market a product much better suited to the needs of its customers. Finally, it may use its resources to develop additional focused products that more closely meet the demands of specific customer niches and segments. These options can give companies an advantage on the markets, which are characterised by intensifying competition and the rapid rate of technological change (Wheelwright & Clark, 1992).

In the Sfinno survey, respondents were asked to indicate the years of major milestones in the innovation's development cycle. These phases included the year of the basic idea, the start of development, the first prototype, commercialisation, the break-even point and first exports. The year of the start of development indicates the year when the development stage began. The year of commercialisation marks the year when the innovation entered the market. When comparing the time of development in the 1980s and 1990s, the results suggest a remarkable shortening of the development process. During the 1980s, the average time for development was some 2.5 years. In the 1990s, the comparable time was only 2.0 years. These results indicate that the duration of the development cycle of innovations was reduced by half a year. This emphasises the feature of the SIN model. As comparable data from other countries is missing, it cannot be said that Finnish companies are fast innovators. However, it can be stated that Finnish companies have become faster innovators, moving towards Rothwell's model.

Rothwell's model of the innovation process is illustrated in detail in Figure 3. As can be noticed, the development of a new innovation nowadays seems to be somewhat chaotic. The characteristics of this model include vertical disintegration along the R&D chain and the growing importance of external sources of technology. This feature is illustrated with triangles and other particles that have been scattered along the development chain of innovation. The arrows between these different objects indicate that the selling and buying of knowledge has become an important factor in this process. Contacts between customers and sellers are in turn helping to create new kinds of relationships between these different factors. Companies also have to develop special kinds of skills in order to operate in this "bazaar". Today, the pharmaceutical industry is a good example of the success of this model.

As has already been mentioned, customers play an important part in this model. Companies are increasingly more dependent on the strong linkages with their customers, especially with the so-called "leading-edge" customers. Along with supplier relations, this emphasises the network role of R&D activity in the SIN model.

Below the SIN model, the time axis has been constructed. This illustrates how different processes - R&D, marketing and manufacturing - are taking place during the development of an innovation. Marketing and R&D make their entries quite simultaneously in the process. In certain circumstances, one can be started earlier than the other. However, emphasis on corporate flexibility and speed of development can be considered as the most critical factors in the whole development process of an innovation.

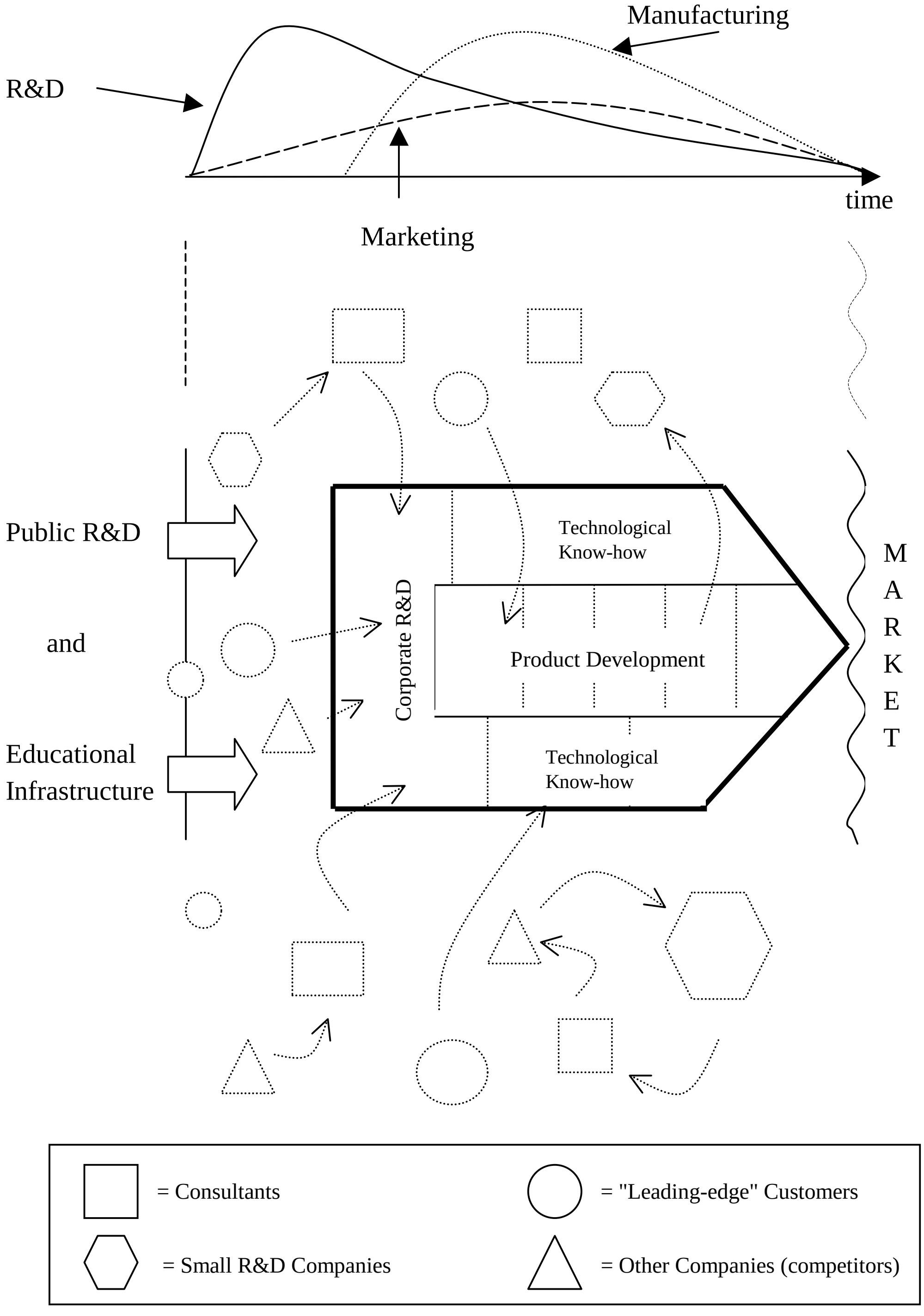

Figure 4. System integration and networking model.

3 Innovations and Profitability in Finland

In the previous chapters, we described five different features of the SIN model in detail. As can be noticed, these features are supported by the Sfinno database. Therefore, it can be stated that the development processes in Finnish companies have already moved towards the SIN model. The network role in the innovation process and the reduction in development times have already become a reality in Finland. However, the economic importance of these features still remains a mystery to the companies. In order to shed some light on the innovative process and its effect on the profitability of firms, an econometric analysis has been carried out.

In this section, we use the Sfinno survey data combined with financial information to examine the SIN model. We focus on examining how the characteristics of the innovative process affect the profitability of the firm. We begin by introducing the model and the variables, followed by regression results.

On the basis of the discussion on the SIN framework, the following model is estimated:

(1) $$PROFIT_{it} = \alpha + X_{SIN_{it}}\beta^1 + X_{inno_{it}}\beta^2 + C_{it}\beta^3 + \varepsilon_{it} \quad ,$$

where X_{SIN} is the vector of the variables suggested by the SIN model and X_{inno} denotes the properties of an innovation defined below. Finally, *C* is a vector of the control variables.

The dependent variable PROFIT, which is the cash flow of the firm, depends on the firm size. Hence, *C* includes a control for size:

PROFIT sales minus variable and fixed operating expenses (material, labour), before interest expenses and depreciation, in millions of Finnish marks. Possible alternatives to cash flow as a measure of profits would be different accounting-based measures, but those have well known problems. This variable has been calculated from the financial data.

STAFF number of employees in the firm in a given year, as indicated in the labour statistics published by Statistics Finland.

In addition, we included two control variables that broadly characterise the quality of an innovation. In this way we hope to distinguish between the properties of an innovative process and the quality of an innovation.

PATENT dummy which equals 1 if the innovation has been granted a patent (EPO, US, etc.) or 0 otherwise. This illustrates the technological quality of an innovation. This and all the remaining variables have been compiled from the Sfinno database.

WORLD dummy which equals 1 if the firm has assessed the innovation as being new to the world market or 0 otherwise.

Apart from the above control variables, vector X_{inno} characterises the properties of an innovation:

NEWTECH significance of new technologies in the development process of an innovation: 1 indicates minor significance, 2 is significant and a value of 3 means very significant.

COMPLEX complexity of an innovation based on the taxonomy by Hyvönen (please see Appendix 2). Values from 1 (low complexity) to 4 (high complexity).

COMPO dummy which equals 1 if the development of an innovation is based on the integration of components and modules or 0 otherwise.

CORE dummy which equals 1 if the innovation is based on the commercialisation of the core technology of the firm.

The most important part of the regression model is the part describing the SIN framework. In accordance with the theory, X_{SIN} consists of variables that describe the customer interface, vertical linkages with primary suppliers, horizontal linkages with other firms, and speed of development:

CUSTOMER dummy which equals 1 if a domestic or a foreign client has had a significant or very significant role in the development process of the innovation, or 0 otherwise.

SUPPLIER dummy which equals 1 if a domestic or a foreign subcontractor has had a significant or very significant role in the development process of the innovation, or 0 otherwise.

JOINT-R&D dummy which equal 1 if the firm's collaboration with another firm has had a significant or very significant role in the development process of the innovation, or 0 otherwise.

BRKTIME $\bar{t}_{brk} - t^{i}_{brk}$, where $\bar{t}_{brk}$ is the sample average for the time from commercialisation to break-even in years. This is about 2.1 years. The time required by a firm for innovation i is t^{i}_{brk}. If BRKTIME is positive (negative), the innovation has turned profitable faster (slower) than on the average. This variable combines the effectiveness of development and marketing of a new product. The longer the development process takes, the more costs are incurred and the longer it takes to reach break-even. On the other hand, a totally new product takes a longer time to develop than an incremental innovation. Once on the market, the former probably generates cash flow faster than, for instance, a slightly improved model variation.

Since the number of financials available for the firms vary considerably, as does the number of years an innovation has been on the market, we use pooled data in OLS regression.

The Sfinno survey data ranges from the mid-1980s to 1998. A total of 701 innovators returned the questionnaire. Some innovations had not been sold and were not on the market at the time of the survey. In those cases, the respondent indicated that the innovation did not generate any turnover. Since we are interested in commercialised innovations that are sold on the market, we excluded about a hundred innovations - or rather inventions - from the sample. Also, a few innovations turned out to be older, i.e. commercialised before 1985 or were brought to the market only in 2000.

The Sfinno innovation data set has been combined with firm level data. The number of employees in a firm comes from Statistics Finland and is available from 1990 to 1997. Due to the policy of the national statistical office, firm-level financials cannot be used. Hence, we have to rely on private databanks, which were not compiled before the 1990s. The financial data are from Asiakastieto Oy. These are available in either electronic or manual form from 1990 to 1999, although mainly the period of 1992-1998 is covered.

It is not reasonable to draw conclusions on the profitability effects of innovations if the gap between commercialisation and the availability of financial statements is wide. The same applies to the three innovations that did not enter the market until 2000. Therefore, we have limited our study to the innovations commercialised between 1986 and 1999. This leaves us with 492 innovations. Financial information can be obtained for about two thirds of those firms. A small number of firms with financials for only one year have been excluded. After combining the survey data with financials, the sample consists of 350 innovations from 275 different firms. The initial restrictions are shown in Table 1.

Table 1. Sample restrictions

Restriction	Innovations left
The whole Sfinno survey	701
Innovations on the market	599
Innovations commercialised 1986-1999	492
Combining survey data with financial data	350

Note that an innovation could have entered the market before, during or after the period for which we have financial information. Since an innovation cannot affect the profitability in a year when it is not sold, we have marked the survey data missing for the years when an innovation was not on the market. Table 2 illustrates the structure of the panel data. Due to missing data, the sample shrinks to 172 innovations from a total of 158 firms. However, we have about four years of financial data, which yields 513 innovation-firm-year observations in pooled data.

Table 2. Structure of the panel data

	time	financial data	survey data
innovation 1	year t_{-2}	not available	denoted 'missing'
innovation 1	year t_{-1}	not available	denoted 'missing'
innovation 1	year t_0	available	survey data used
innovation 1	year t_1	available	survey data used
innovation 1	year t_2	available	survey data used
innovation 1	year t_3	available	survey data used
innovation 1	year t_4	not available	denoted 'missing'

The financial statement data have been deflated with a monthly producer price index to the base month of June 1995. Fiscal data that differs from the calendar year has been multiplied by *m*/12, where *m* denotes the length of the fiscal year in months.

In the regressions, we begin with a basic model with mainly the SIN variables. Subsequently, the model is extended by adding the variables characterising the innovation. Table 3 presents the results. All figures are in millions of Finnish marks.

Starting from the control variables, we can see that an additional employee increases the sales of the firm by about FIM 300 000, which is a reasonable figure. The explanatory power of the equations is good with an R^2 of over 80 per cent.

A granted patent has a positive effect on the profitability of an innovation. The size of the impact is considerable, at about the same level as the SIN model variables. However, the other quality-related variable WORLD does not have any effect on profitability. It seems that a unique product on the world market - as defined by the respondent - is not as good an indicator as a patent. In other words, uniqueness does not guarantee that the innovation passes the market test.

The SIN model suggests that vertical linkages between the innovator and the customers or suppliers are vital for a successive innovative process. This is clearly supported by the results. The point estimate suggests that the profits of firms with such linkages are double those of firms which innovate independently. SUPPLIER is statistically significant at the 1 per cent confidence level in all estimations. CUSTOMER becomes marginally significant once we add more variables describing the process and collaboration with other firms. Similarly, there is weak evidence that joint product development has a positive effect on profits.

The magnitude of the effects in equation 4 suggests that the supplier relationship in the development process is more closely related to the profits than customer involvement. Later, we will see that this relationship is opposite for smaller firms.

The speed of development and effectiveness in turning the innovation into a profitable product have a statistically significant effect on profitability. A half a year off the development time increases the profits by approximately ten per cent. The same applies to the role of new technologies in starting the innovative process, although the size of the technology effect is higher, implying an increase of 20 per cent in profits.

Also, the complexity of an innovation appears to have a direct effect on profitability, even if the R&D costs of complex innovations are not necessarily higher than those of less complex ones. Note that complexity and the ability to use new technologies in the innovative process can also reflect the accumulation of capabilities and knowledge. Leiponen (2000b) found that the effect of a firm's knowledge base - skills of employees, patents - is complementary to innovative activity. It is possible that COMPLEX and NEWTECH act as a proxy for what Leiponen calls dynamic competencies. These tend to reinforce the effect of innovative activities.

Table 3. Estimation results, basic sample

Basic sample (158 firms, all innovations)
Variables in millions of Finnish marks (FIM 1= EUR 0.168)
Dependent variable: PROFIT

	1	2	3	4
STAFF	0.31***	0.31***	0.31***	0.31***
	(47.75)	(45.87)	(45.92)	(45.56)
PATENT	75.38***	88.46***	86.03***	90.60***
	(2.44)	(2.79)	(2.71)	(2.82)
WORLD	5.48	-11.78	-15.87	-17.13
	(0.15)	(-0.32)	(-0.43)	(-0.45)
CUSTOMER	79.82**	59.23*	63.34*	59.97*
	(2.36)	(1.68)	(1.78)	(1.66)
SUPPLIER	88.92***	112.61***	110.99***	109.52***
	(3.04)	(3.72)	(3.67)	(3.57)
BRKTIME	19.85***	24.14***	25.22***	25.50***
	(2.78)	(3.13)	(3.24)	(3.25)
NEWTECH	40.74***	32.93**	34.14**	41.65***
	(3.18)	(2.36)	(2.40)	(2.79)
COMPLEX		54.26***	52.07***	49.86**
		(2.77)	(2.61)	(2.45)
COMPO			15.49	22.58
			(0.37)	(0.53)
CORE			56.95	64.65
			(1.38)	(1.53)
JOINT-R&D				83.42*
				(1.69)
CONSTANT	-305.38	-417.88	-441.93	-458.87
	(-6.44)	(-6.54)	(-6.39)	(-6.46)
Observations	513	476	476	466
Deg. Fr.	505	467	465	454
Adj. R-sqr	.82407	.82327	.82348	.82453
F-test	F(7,505)=343.60	F(8,467)=277.59	F(10,465)=222.59	F(11,454)=191.64
Mean of dep. variable	173.208	152.078	152.078	155.287
std. dev.	759.494	754.687	754.687	762.437

t-statistics in parentheses
*** *significant at 1 per cent confidence level*
** *significant at 5 per cent confidence level*
* *significant at 10 per cent confidence level*

The remaining property of the SIN model is product design that combines the old with the new. This is related to the nature of the innovative process. Two different dummies for the background knowledge - CORE and COMPO - describe whether the firm has focused on commercialising its core knowledge or combining existing modules (system knowledge). This choice did not have a clear linkage to profitability. In addition, we also tested the effect of commercialisation of service concepts and process knowledge. Neither of these had any effect on profitability. A possible explanation is that a firm can have a wide knowledge base that builds on many types of knowledge. This was indeed the case for big companies. Also, the type of knowledge is probably not as important as the way it is used in the innovative process. Measuring this would, of course, be a difficult task. The problem of causality is also inherent in this kind of estimation, since innovations can result in profitability but also vice versa. Endogeneity should not distort the results unless we believe that profitability affects the properties of the innovative process, e.g. the way a firm co-operates with its partners. Since we have only innovative firms in our sample, this is not likely to cause any bias in the results.

A more fundamental question relates to the impact that a single innovation can possibly have on the success of an entire company. The above estimation included all innovations that are still on the market. It could be argued that innovations with a very small share of a firm's turnover could not have such a radical impact on profits. Therefore, we can check the robustness of the results by concentrating on innovations that are commercially significant for the firm. In the questionnaire, the innovators gave the innovation's share of turnover in five classes: 0 per cent, 1-5, 5-25, 25-50 and over 50 per cent. We excluded innovations with less than 5 per cent turnover shares. Table 3 presents the results.

The number of observations is halved to about 300. If we look at the mean of the dependent variable, we note that bigger firms have dropped out of the sample. This is natural since an innovation's share of turnover decreases with firm size: bigger firms have more innovations and a single one is not as likely to attain a high turnover share as in a small firm.

The results are rather similar to the earlier ones. The explanatory power stays high at around 80 per cent. By and large, the model seems to be robust to changes in sample. The signs remain the same with the exception of COMPLEX, which is not statistically significant. One can also notice that the effect of customer collaboration grows in this sample with smaller firms, and the opposite holds for suppliers. It seems that being market-oriented in product development grows in importance for smaller firms. This is in line with the survey results of the Sfinno report (Palmberg et. al 2000), which indicated that small firms build on commercialising a core technology and finding a market niche.

The impact of patents is of the same magnitude as in the whole sample. Considering the smaller mean of turnover in this sample, patents matter relatively more. The same applies to new technologies, which are statistically significant and positive. Joint R&D has the biggest impact in the fourth equation of Table 4. Co-operation with rival firms also has a bigger impact on profits than in Table 3. The interpretation is that the profits of firms which have developed innovations together with rivals are double those of other firms. However, the effect of patents is nearly as great, while customer involvement comes very close.

Table 4. Estimation results, small sample

Small sample (157 firms, innovations with a minimum of 5 per cent share of turnover)
Variables in millions of Finnish marks (FIM 1=EUR 0.168)
Dependent variable: PROFIT

	1	2	3	4
STAFF	0.31***	0.31***	0.31***	0.31***
	(35.82)	(31.67)	(31.47)	(31.29)
PATENT	89.10***	108.46***	109.07***	110.81***
	(2.59)	(2.99)	(3.00)	(3.01)
WORLD	-54.12	-60.31	-61.49	-54.64
	(-1.25)	(-1.37)	(-1.40)	(-1.20)
CUSTOMER	113.58***	99.97**	95.57**	97.11**
	(2.80)	(2.36)	(2.22)	(2.23)
SUPPLIER	65.96**	72.59**	67.89*	60.33*
	(1.95)	(2.04)	(1.90)	(1.66)
BRKTIME	28.74***	35.87***	36.49***	38.49***
	(3.66)	(4.12)	(4.16)	(4.35)
NEWTECH	52.94***	48.57***	44.99***	56.81***
	(3.70)	(3.03)	(2.72)	(3.27)
COMPLEX		21.75	23.28	19.92
		(0.91)	(0.96)	(0.81)
COMPO			-26.56	-12.96
			(-0.50)	(-0.24)
CORE			35.55	53.98
			(0.70)	(1.02)
JOINT-R&D				137.58**
				(2.43)
CONSTANT	-282.70***	-333.53***	-332.38***	-369.31***
	(-4.73)	(-4.04)	(-3.70)	(-3.91)
Observations	319	295	295	287
Deg. Fr.	311	286	284	275
Adj. R-sqr	.81576	.7894	.78989	.79401
F-test	F(7,311)=202.14	F(8,286)=138.76	F(10,284)=111.53	F(11,275)=101.22
Mean of dep. variable	136.585	103.179	103.179	106.006
std. dev.	668.299	632.583	632.583	641.138

t-statistics in parentheses
*** *significant at 1 per cent confidence level*
** *significant at 5 per cent confidence level*
* *significant at 10 per cent confidence level*

4 Conclusions

The system integration and networking (SIN) model emphasises the role of networks in the innovative process. Strategic partnerships with leading customers, subcontractors and joint research with rival firms give a realistic picture of modern innovative activity. Integrating the R&D process not only with science but also with markets is the way to organise the innovation process. It is estimated that nowadays formal R&D represents two thirds of the whole innovative process, while one third of R&D input come from competitors, customers and subcontractors.

The SIN model view of the innovative process can be best analysed in the context of the object approach. The SIN model describes many aspects of the innovative process. This requires detailed information on individual innovations and their development. In this paper, we used Sfinno survey data and financial information to analyse the effect of the SIN model variables on the profitability of firms.

The results suggest that the key features emphasised by the model are indeed important factors in determining the success of a firm. The role of customers in the development process has a bigger effect for smaller firms with innovations of higher turnover shares. For larger firms, supplier involvement had a bigger effect on profits. A six-month shorter development time compared to rivals leads to an increase of about ten per cent in profits.

A granted patent appears to have a strong effect on profitability and also measures the quality of the innovation better than just being novel on the world market. The latter variable did not have any statistically significant effect on cash flow. Similarly, the complexity of an innovation was not consistently related to improved profitability. In fact, the relationship existed in the whole sample, but not among the smaller firms or innovations with higher turnover shares. One possible explanation is that complexity and size are correlated so that bigger firms introduce more complex innovation. A simple correlation analysis does not support this explanation. Alternatively, other factors such as engaging in joint R&D are more important for smaller firms in explaining profitability, driving the explanatory power of the innovation properties to zero.

The use of new technologies was related to higher profits but other characteristics of the innovation process, such as focusing on the commercialisation of core knowledge or combining different modules, did not have any effect on a firm's profits. It seems that the knowledge can be based on multiple areas, which can all result in commercial success if the innovation process is otherwise effective.

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Appendix 1: The Data

Sfinno Data

The Sfinno data have been documented in detail in a few earlier papers.[3] This is a brief summary of the data. We make a distinction between the whole data (about 1500 innovations from about 1000 firms) and a subset called the survey data (additional information on over 700 innovations, based on a survey of innovators).

The Whole Data

In the mid-1990s, VTT Group for Technology Studies began a research project called Finnish Innovations (hereinafter Sfinno). The aim of the Sfinno project was to provide a new perspective on structural and technological change in Finnish industry during the 1980s and 1990s from the viewpoint of individual innovations. For this purpose we constructed a unique database consisting of 1482 Finnish innovations commercialised during the 1980s and 1990s.[4] Our definition of an innovation relies loosely on the definitions provided in the Oslo Manual (1997). We defined an innovation as an invention that has been commercialised on the market by a business firm or the equivalent. As a minimum requirement, the innovation had to pass successfully through the development and prototype phase, involving at least one major market transaction. The bottom line for inclusion of an innovation in the database was thus "a technologically new or significantly enhanced product compared with the firm's previous products". We have only included innovations that have been commercialised by firms registered in Finland.

The whole data was compiled using a combination of three different methodologies for the identification of innovations: expert opinion, reviews of trade and technical journals, and reviews of the annual reports of large firms. Of these three, expert opinion and literature-based reviews are relatively well established methodologies

[3] The structure and methodology of the Sfinno data have been described in detail in Palmberg *et al*. 1999. First results were presented in Palmberg *et al*. 2000 and comparison of coverage to CIS data in Leppälahti (2000).

[4] The number of innovations varies, depending on the exact criteria that we apply in defining innovations. The grand total is 1620 innovations, including inventions that have not reached the markets.

in innovation studies similar to Sfinno (see e.g. Townsend *et al*. 1981, Wallmark & McQueen 1991, Kleinknecht *et al.* 1993). The reviews of the annual reports of large firms, however, take a somewhat different point of departure since the innovations were identified through our subjective judgement in collaboration with the firms.

The use of expert opinion for the identification of innovations began already in 1992. It involved a large number of experts representing different industrial and technological fields from industry, the Technical Research Centre of Finland, the National Technology Agency of Finland (Tekes) and the universities of technology. These experts were asked to list significant innovations according to our definitions and criteria and to identify the year of commercialisation and the commercialising firm. This exercise resulted in the identification of 258 innovations.

The literature reviews were undertaken during the second half of the 1990s. From a list of some 60 eligible Finnish trade and technical journals we selected 18 to cover as extensively as possible all the major industries. The focus was on articles dealing with the introduction of new products which conformed to our definitions and criteria for an innovation. Listings of new products were avoided, emphasising the editorial content of the journals. They listed and described these, noted the year of commercialisation (if available) and the name of the commercialising firm, the journal number and the relevant pages. This resulted in the identification of 1040 innovations, the majority of all the innovations in the database. In addition, we have included lists of award-winning innovations in the literature reviews.

Due to the importance of a few large firms in the Finnish economy, they were included on a case-by-case basis (altogether 22 firms), since we feared that they would not be covered sufficiently and in enough detail in the literature reviews. The selection of firms was also made on the basis of their R&D spending and patenting, as it was assumed that firms investing heavily in R&D and patenting could also be considered innovative. Again, a group of students helped by first listing all the new products that these firms had launched during 1985-98. The firms were then approached with the lists of product launches and the definitions and criteria of an innovation, and they were asked to pick out those products which they considered especially important and innovative. In this way, a group of 137 innovations were identified. Another group of 138 innovations has been identified more or less unsystematically from miscellaneous written sources, the world wide web or by researchers at the VTT Group for Technology Studies.

Our combination of different methodologies for the identification of innovations was intended to secure good coverage of the data across different industries and firm size groups. On the other hand, this also implies that it will be more difficult to control for biases. These biases might, for example, arise if the experts were inclined to identify relatively more innovations originating from bigger firms, while the literature reviews identified relatively more innovations from smaller firms. Another bias in favour of innovations from larger firms might arise from the review of annual reports on a case-by-case basis.

In order to check for biases, we have cross-compared the source of innovation identification across the firm size groups. The results of these exercises confirm that a relatively larger share of innovations from smaller firms were indeed identified through literature reviews. On the other hand, the experts did not have a noteworthy bias in favour of innovations from bigger firms. Moreover, the share of innovations which were identified from more than one source is relatively small, indicating that the combination of different methodologies has indeed enhanced the coverage of the database.

The Survey Data

Owing to various practicalities related to the extensive time period covered and organisational changes among the firms, a significant amount of preparatory work was required before we could mail the questionnaires. The major criteria for the survey was that the firm was still active according to the firm registers and that it was possible to identify a knowledgeable respondent who had followed the various development phases of the innovation. This was deemed especially important in the case of larger firms. In the case of small firms, we often picked the firm manager on the assumption that he would pass the questionnaire on to the relevant person.

The mail survey was undertaken in four successive phases between December 1998 and October 1999. Each phase was followed up with two reminders and an e-mail message in cases where we had access to the address. In October 1999 a final, fourth reminder was sent to all respondents who had not yet answered. In the meanwhile, the questionnaires received were run through a control program designed to check for internal inconsistencies in the answers. All inconsistencies led to further contacts with the respondents with the aim of minimising item non-response. In some cases, as a consequence of interaction with the respondents, the name of the innovation was altered.

The response rate for our mail survey reached 64 per cent. We posted 1235 questionnaires; 689 were returned. The overcoverage, i.e. the number of innovations relating to defunct firms, was 151, despite the fact that we had tried to exclude these from the survey at the outset. Therefore, the survey data in practice covers only active firms, even though the innovations might already have exited the market. After the above-mentioned criteria that we adopted to exclude, for instance, uncommercialised inventions, we were left with 642 innovations in the survey data.

Appendix 2: System Integration and Networking Model

Underlying strategy elements:

* Time-based strategy (faster, more efficient product development)
* Development focus on quality and other non-price factors
* Emphasis on corporate flexibility and responsiveness
* Customer focus at the forefront of strategy
* Strategic integration with primary suppliers
* Strategies for horizontal technological collaboration
* Electronic data processing strategies
* Policy of total quality control

Primary enabling features:

* Greater overall organisational and systems integration:
    - parallel and integrated (cross-functional) development process
    - early supplier involvement in product development
    - involvement of leading-edge users in product development
    - establishing horizontal technological collaboration where appropriate
* Flatter, more flexible organisational structures for rapid and effective decision-making:
    - Greater empowerment of managers at lower levels
    - empowered product champions/project leaders
* Fully developed internal data bases:
    - effective data sharing systems
    - product development metrics, expert systems
    - electronically assisted product development using 3D-CAD systems and simulation modelling
    - linked CAD/CAE systems to enhance product development flexibility and product manufacturability
* Effective external data links:
    - co-development with suppliers using linked CAD systems
    - use of CAD at the customer interface
    - effective data links with R&D collaborators.

Source: Rothwell, 1992b.

Appendix 3: Complexity Taxonomy by Hyvönen

Kleinknecht *et al.* (1993) divided innovations into three classes by complexity. High complexity referred to a system comprising a large number of functional parts and coming from several different disciplines. Innovation of medium complexity in the Kleinknecht study was a unit of more than functional parts and required the integration of a few different disciplines. Innovation designated as being of low complexity required knowledge from one discipline and consisted of only one part.

Hyvönen's taxonomy was born in order to help the practicality aspect in the Sfinno database. The problem with Kleinknecht's typology was that two aspects – the artefactual and development process - were mixed. The assumption was that the simpler the structure of an innovation, the less development is required. The obvious exceptions are enzymes and medicine, which have a simple structure (e.g. a pill) but require extensive development. However, Kleinknecht's taxonomy was difficult to implement in Sfinno. Hyvönen developed a taxonomy which divides Kleinknecht's medium complexity innovations into two groups, depending on the complexity of development.

Hyvönen's taxonomy is based on the description of innovation, taken from the Sfinno database. In some cases when the description of innovation was not enough, more information about the innovations was collected by visiting websites. Overall, Hyvönen's taxonomy can be seen as a qualitative variable describing the complexity of innovations, especially in Sfinno. The following list introduces this specific taxonomy in more detail. It has not been presented before.

1. Low artefactual complexity/ low developmental complexity
   Innovation is a simple unit

2. Medium artefactual complexity/ low developmental complexity
   Innovation is a unit, development is based on knowledge base from one discipline
   Examples: electronic wheel chair, drill

3. Medium artefactual complexity/ high developmental complexity
   Innovation is a unit, development is based on knowledge base from several disciplines

Examples: pharmaceuticals, software, generator

4. High artefactual complexity/ high developmental complexity

Innovation is a system consisting of several functional parts, development is based on several different disciplines

Examples: paper machine, mobile phone network, cruise ship

Working Papers - Työpapereita

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Innovations and the Success of Firms

Recently, while inter-firm competition has been increasing on the markets, more attention has been paid to the development process of new products - innovations. The role of customers, subcontractors and competitors has become more crucial during the innovative process. Despite the important nature of this process, the amount of research in this field has been extremely limited, even non-existent.

In this report, we attempt to shed light on the innovative process and its effect on the profitability of firms. We combine the Sfinno innovation data with firm financials to study the characteristics of the innovation process and the success of firms. The theoretical basis of the study is the "System Integration and Networking" model by Rothwell. The main emphasis is on analysing how factors such as co-operation in developing innovations, development times and the nature of knowledge affect the profitability of firms.