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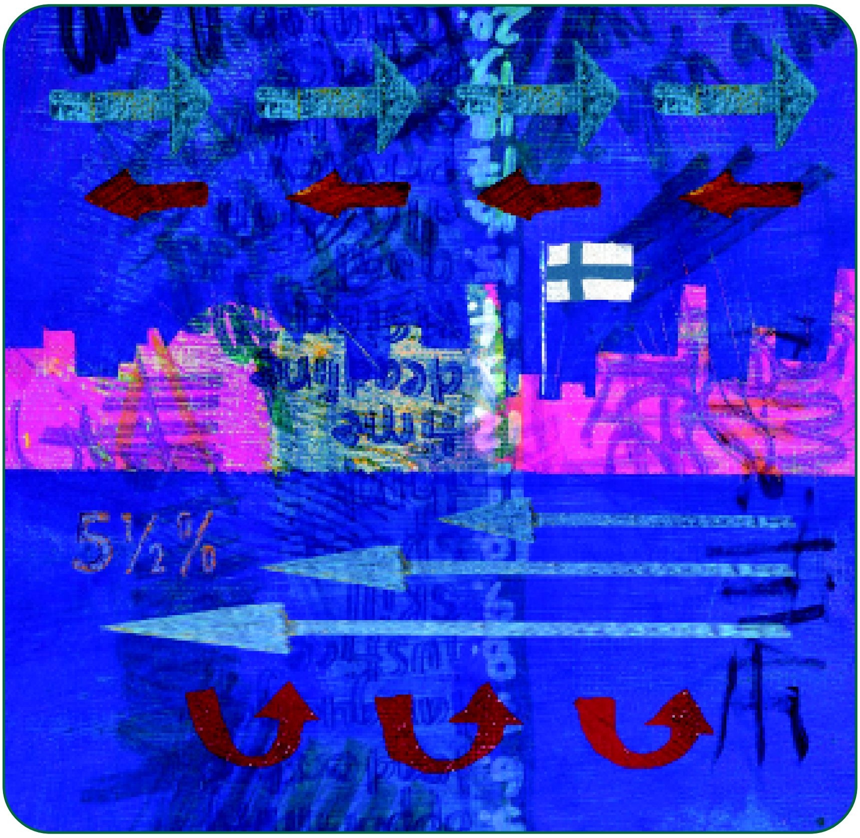

Bernd Ebersberger & Olavi Lehtoranta

Pattern of Innovative Activities among Finnish Firms

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Abstract

This study summarizes the research on the innovation activities of Finnish firms and its many facets drawing on vast data supplied by Statistics Finlands, register and survey data. The authors set out to analyze the impact of public funding, the pattern of collaboration for R&D and their determinants, the impact of foreign ownership on innovation activities and firm performance, and, finally, the returns from innovation, their determinants and distributions.

Preface

This report summarizes some of the results of the Dynamic Patterns of Innovative Activities among Finnish Firms research project. As an *a priori* restriction, the reader of the report has to be aware of the fact that the authors do not intend to give a comprehensive picture of all the research conducted. Rather, the authors have bundled together a set of research papers that were written during the project. The uniting feature of the research presented here is that it utilizes certain data sources to tackle the research questions. The data sources used are the different waves of the Community Innovation Survey (CIS 1 through CIS 3), the Database of Finnish Innovations, and various register-based data sources from Statistics Finland, such as: business register, patent register, employment register and the like, and – last but not least – data on companies receiving funding for R&D supplied by the National Technology Agency of Finland (Tekes). The research was carried out with funding from Tekes and the Ministry of Trade and Industry under the ProACT umbrella. The authors gratefully acknowledge the financial commitment without which this research could not have been carried out. The authors much appreciated the efficient management conducted by the programme management team, and the efforts by Tarmo Lemola in particular. The authors also appreciate the open and inspirational discussions with Tekes' staff; in particular, Eija Ahola and Pekka Pesonen offered insightful advice and contributed helpful suggestions. The ProACT program offered a rich set of occasions for the exchange of ideas, insights and inspiration with other projects.

The steering group of the project – Kaija Hovi, Ari Leppälahti, Torsti Loikkanen, Ari Mikkelä, Pentti Vuorinen and Mikael Åkerblom – helped to sharpen the focus of the project and contributed stimulating comments on countless occasions.

The research was conducted when Bernd Ebersberger was with VTT Technology Studies and visiting Statistics Finland. He wishes to emphasize the open and inspiring atmosphere in both institutes.

Being with VTT enabled Bernd to get a comprehensive insight into the Finnish national system of innovation and beyond. The exciting discussions and the exchange with colleagues, who turned into friends, are too numerous to mention.

The people, though, can be mentioned: Kirsi Hyytinen, Pirjo Kutinlahti, Sirkku Kivisaari, Erja Väyrynen, Jukka Hyvönen, Torsti Loikkanen, Juha Oksanen and Jani Saarinen.

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Last but not least, Bernd wishes to extend his special thanks and gratitude to Tuomo Pentikäinen, who started all this and initiated Bernd's stay in Finland.

Karlsruhe and Espoo, March 2005

Bernd Ebersberger

Olavi Lehtoranta

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1. Introduction

This study originates from our research into the innovation activity of Finnish firms. It also originates from the very insight that innovation activities are essential to maintain the competitiveness of an economy, to sustain its growth and to solve some of the most pressing societal problems. We presuppose that innovation activity is beneficial for the economy and the society at large, and that policies to foster innovation activities have to know a good deal about the activities themselves and the firms carrying out the innovation activities. Although it is a trivial observation that within an economy no two firms are alike, we maintain the view that with certain simplification and certain – not completely unreasonable – assumptions we can find patterns among innovation activities and among innovation active[i] firms.

Our view of innovating firms is based on three basic perspectives that shed evolutionary light on the firm as an object of research. The first is the behavioural foundation of the evolutionary approach, the resource-based view of the firm and the knowledge-based approach of the firm (cf. Rahmeyer 2001).

Behavioral Foundations

Evolutionary theorising in economics endeavours to describe and explain the real behaviour of firms; furthermore, it does so on a higher level of reality. The focal point of the discussion of evolutionary economics from a behavioural point of view is the production of goods and services, including the impacts of technical and organisational novelty. The behavioural view is comprised of three building blocks: (1) bounded rationality and behavioural routines, (2) novelty creation, and (3) a selection mechanism.

A specific characteristic of these processes is uncertainty, which cannot be treated adequately by drawing on stochastic distributions – which would, in a sense, refer to the concept of risk. Therefore, the assumption of perfect rationality of the actors, underlying traditional models cannot be maintained; instead, the concept of perfect rationality is substituted by the concepts of bounded and procedural rationality. Companies are not assumed to be optimising; rather, they exhibit rule-like behaviour. This type of behaviour is denoted routine, which is used to label the processes of how things are done (Winter 1986). Under the notion of routines, (Nelson & Winter 1982) subsume repeated, hierarchically structured behavioural patterns of production activities, investment activities and innovation activities. Routines can be thought to contain the entire knowledge, experiences and skills of a firm. In this regard they are considered a representation of the individual and the collective knowledge stock of a firm. Routines preserve the continuity and internal stability of the firm (Winter 1975).

The active search for new opportunities instead of maintaining the old routines creates behavioural novelty. Intentional and problem-focused search activities and learning can gradually modify given routines. The search activities are induced by profit creation rather than profit maximisation. These activities, although intentional and problem-focused, are characterised by strong cumulativeness and path dependence (e.g. Teece et al. 1994). Routines are modified once they no longer yield a satisfactory result or once new technical and organisational opportunities become available (Winter 1975).

This routinized behaviour is in contrast to the maximising behaviour of firms implied in the mainstream economic reasoning. The variety of routines available creates a variety of behavioural patterns, which support the economic change.

Mutation in the biological evolution can be regarded as a metaphor for the creation of behavioural novelty (Nelson & Winter 1982). However, the major difference is that mutation works randomly, whereas firms actively search for new opportunities.

The successful routines survive in the population of firms, whereas the unsuccessful routines are bound to vanish. Either the non-successful routines are changed intentionally by the firm itself, or the firm, as a carrier of the routine, vanishes from the markets. In both cases the routines vanish.

As pointed out above, firms intentionally modify and select routines. The evolutionary process in economics can be regarded at least to a certain degree as an active process shaped by the participants. This is in clear contrast to the biological understanding of evolution. Evolution there is an anonymous process that cannot be actively influenced by the subjects.

However, we also have to emphasise that organisations are not only actively shaping their environment. Rather are firms conceptualized as adaptive systems, suggesting that contextual variables have a causal influence on firms' routines (Souitaris 2002).

This feature of intentionality underpins the causal role firms play in the process of economic development (Rahmeyer 2001, p. 29).

Resource-based view

By means of their strategies, their management and their organisation structure, as well as by means of their specific skills and competencies, firms can intentionally create heterogeneity in terms of their market return and their resource base.

Strategies encompass all the long-term commitments of a firm that determine its targets. The strategies are based on the firms' internal resources (e.g. Porter 1991). The actual behaviour and the internal organisation of the firm to achieve the set targets are the structure of the firm. Both strategy and structure jointly determine the core activities of a firm and contribute to the development of sustained competitive advantages. Due to bounded rational behaviour and the routinized behaviour of firms, both structure and strategy reveal a high degree of persistence.

A firm's skills and competencies complement the firm's routines. Competencies relate to the co-ordinated use of skills. Both skills and competencies are the bases for the intentional actions taken by firms. As such, they are the foundation of a firm's strategies. "A firm's competence is a set of differentiated technological skills, complementary assets, and organisational routines and capacities that provide the basis for a firm's competitive capacities in one or more businesses" (Teece et al. 1994, p. 18).

The resource-based view maintains that the firm's market success is determined by the strategies and structure as well as by the skills and competencies of the firm. Skills and competencies are generated by firms' search processes and innovation processes. They are cumulative and path-dependent.

The cumulativeness and path dependency create inter- and intra-sectoral heterogeneity. Here we stress the important role heterogeneity and variety play in the development processes. Due to the assumption of perfect rationality, homogeneous actors and technologies are assumed and analysed in traditional models. Heterogeneity as a source of novelty is by and large neglected, or treated only as a temporary deviation from homogeneity.

In evolutionary economics heterogeneity is a rather permanent feature of the economic actors. Hence there is no adequate description of the economic system without taking the variety of actors into account. Evolutionary economics does so by adopting a population approach. The industrial dynamics – especially the creation of innovation – cannot be understood without that population approach.

Firms' heterogeneity concerns the actions taken. With reference to the actions, two kinds of heterogeneity can be discriminated (Cantner 1996, Saviotti 1996):

1. *Vertical heterogeneity*. Although firms carry out the same actions they differ in their performance. These differences in performance can, on the one hand, be attributed to different endowment with resources. On the other hand, they can also be caused by the firm's different experiences or different skills and capabilities.

2. *Horizontal heterogeneity*. Different firms carry out different actions. These differences can also be attributed to different endowment with resources. However, it can also be caused by firms' different strategic decisions. Thus horizontal heterogeneity can be attributed to firms' discretionary differences (Nelson 1991).

This does not mean that firms are thought to be completely heterogeneous, i.e. each firm is different from all others in respect of all characteristics. Rather, there are certain subgroups that have certain traits in common, allowing for a description at a reduced level of complexity (Comim 2000, Martin 1994). Firms can thus be classified on their degree of similarity with regard to some given criteria.

Knowledge-based view

The knowledge-based view of the firm maintains that the firm is an institution integrating knowledge (Grant 1996). Learning and knowledge acquisition is at the core of the firm's activities to sustain its economic viability. Firms learn and acquire knowledge

1. through their own scientific and applied research, and the subsequent introduction of innovations to the market

2. through the experience of their employees in the production process by learning by doing or by learning by using

3. through collaboration with external knowledge sources

    (a) with universities and research laboratories

    (b) with customers

    (c) with competitors

    (d) with suppliers

    (e) with consulting companies

4. through fluctuation of personnel

5. through reverse engineering of marketed commodities.

Utilising the internal knowledge sources is advantageous in terms of transaction costs, in terms of utilisation of the firm-specific knowledge and in terms of intellectual property rights. The risks involved and the high costs associated with internal R&D are considered disadvantages.

R&D collaboration, however, is associated with certain advantages. Briefly, they arise due to the internalisation of the returns of R&D, due to cost sharing and due to knowledge sharing.

However, although companies actively try to improve their knowledge base, it remains incomplete as the information is far from perfect and the information processing capabilities are limited.

Based on this incomplete knowledge and information, cost-benefit analyses concerning innovations cannot easily be carried out. In this light the introduction of novelties mutates from optimal cost-benefit considerations to collective experimental and problem-solving processes. The knowledge base of the actors is no longer perfect; instead, a gap opens up between the competencies and difficulties that are to be mastered (Heiner 1983). There are two reasons for this C-D gap:

1. Technological uncertainty introduces errors and surprises.

2. The very nature of knowledge avoids unrestricted access. Knowledge in general, and new technological know-how in particular, is no longer considered freely available, but local (technology-specific), tacit (firm-specific), and complex (based on a variety of technology and scientific fields). If companies want to understand and use the respective know-how, specific competencies are necessary, which have to be built up in a cumulative process over the course of time.

The knowledge-based view also deals with the time dimension, in which the updating of knowledge and learning is a prerequisite for the emergence of novelties for the knowledge-based view. By their very nature, these processes are truly dynamic, meaning that they occur in historical time. So the current state of an actor is to a large extent the result of historical events shaping his or her current condition.

One of the main findings above is that innovation cannot be adequately studied in a framework just by using static models. To be able to talk about innovation realistically one has to refer to dynamic concepts. Static approaches disregard time as one of the dimensions that shape the space in which economic and technological activities take place. Time plays an important role in the theoretical reasoning discussed above. The behavioural view, the resource-based view and the knowledge-based view agree upon the importance of cumulative processes and path dependence. Put simply, what they agree upon is: history matters. It matters for the modification of existing routines, and for the emergence of new routines (the behavioural view), it matters for the development of skills and competencies (the resource-based view) and it matters for learning and the creation of new knowledge (the knowledge-based view). Firms are the agents of technological and economic development. The firm-level perspective is relevant. Yet to obtain a more detailed understanding of the dynamics of firm behaviour we also might want to look either at the project level or at an aggregated sectoral or even at the macro level. Heterogeneity is both a cause and result of evolving economic systems. Heterogeneity concerns resources and activities as well as performance.

The multi-faceted phenomenon 'innovation' is based on a plethora of activities. This study suggests focusing on the various types of activities that are carried out simultaneously to generate innovation success. A clear timely structure as suggested by the linear model[ii] does not exist.

Focus of the study

The resource-based view stresses the idea that resources are an essential factor in moving from failure to success in innovative efforts. Resources can be acquired in various ways. One way is to get public subsidies for R&D activities, as the application for funding is one activity in the wide range of actions to source the R&D efforts. As such, it qualifies as innovative activity in our definition. The key question in the context of public funding is whether it has an impact on firms' success of innovative activities. As public funding can influence both the technological process and the market process, we can ask this question in two different ways:

Does public funding have an impact on firms' generation of innovative output?

The innovative output is comprised, for example, of patents, of inventions, of innovations or of knowledge. As both inventions and knowledge are extremely hard to measure, and because innovation counts cannot clearly be qualified in CIS Surveys, we restrict this question to the analysis of the impact of public subsidies on firms' patenting behaviour. The second way to ask this question about the impact of public subsidies relates to outcome rather than to output. In our discussion above we qualified outcomes as firm growth in terms of employment growth and growth of turnover, in terms of market share, etc. Putting the indirect effects aside, the direct effects of public subsidies are to increase the innovativeness of the economy. This innovativeness, however, does not seem to be the final goal. It is an intermediate goal to get welfare improvements. It is commonly argued that innovation creates welfare improvements by generating higher income and creating increasing employment. We can, therefore, ask whether public subsidies increase employment.

Does public funding have an impact on firms' generation of innovative outcome in terms of employment growth?

As the knowledge-based view emphasises the knowledge creation and knowledge proliferation, collaboration activities for innovation clearly belong to the innovative activities. Patterns can be found in terms of the selected collaboration partners. As firms are proactive in shaping their immediate environment, the question of collaboration motives arises. In light of the discussion above, the question of the extent to which successful collaboration history matters also arises.

What are the patterns of collaboration for innovation?

Do the patterns of collaboration change over time?

What are the past and current determinants of collaboration?

Both the knowledge and the resource-based view would argue that the innovation activities of companies differ for different types of ownership, such as domestic ownership versus foreign ownership. Foreign ownership offers a wider range of knowledge sources and a larger pool of resources that a company can draw from. As a corollary, one would suggest that this influences the intensity of innovation activities and the way in which these activities are performed.

Does ownership matter for innovation activities?

Although the previous discussion clearly relates to the outcome of innovative activities, it has a strong connection to the public funding, which, according to our definition above, can be labeled input into innovative activities. However, as the outcome categories represent the results of innovative activities, we also have to focus on how the returns to innovative activity are distributed. We are measuring the returns to innovative activity by the turnover generated by new products, or by its share of the total turnover.

How are the returns to innovation distributed across the innovators?

Looking at the distribution of returns implies a meso or macro perspective on the innovative activities and their return. As this project has a firm-level focus, we can also investigate the changing position of firms within the population of firms. This restores the dynamic view of the project and time returns to the analysis.

What impact does R&D have on the returns to innovation?

Approach

In most of the following chapters we will derive a set of hypotheses from the literature, and subsequently test them. The only exception to this approach is the rather exploratory approach taken in Section 5.

Section 2 discusses the impacts of public R&D funding on the innovation output – measured by patents – and on the innovation outcome – measured in terms of employment demand. Collaboration for innovation is dealt with in Section 3, where we analyse the use and appreciation of knowledge-intensive services in the traditional industries and elaborate on the determinants of innovation collaboration. Section 4 then discusses the impact ownership – foreign ownership in particular – has on innovation activities. Finally, Section 5 investigates the returns companies receive for their innovation activities.

2. Impacts of public R&D funding

Some of the results discussed here are also presented in Ebersberger and Lehtoranta (2003), Ebersberger (2004a) and Ebersberger (2004b).

2.1 Introduction

This part of the study focuses on the question of whether public R&D subsidies have a positive impact on the labour demand of the subsidised firms. The basic, very stylised, rationale giving rise to this question builds on the fact that public subsidies for R&D intend to foster innovation, innovation in turn causes firm growth, which also increases the subsidised firms' labour demand.[iii]

This line of reasoning can be decomposed into two distinct steps. The first step establishes the link between public subsidies and increased innovativeness. The microeconomic theory explains State intervention in the innovation process by the gap between social and private returns caused by market failure. The gap leads to a sub-optimal level of R&D activities; the gap itself being caused by the public good nature of the results of R&D, causing only partial appropriability of the returns of the R&D investment (Arrow 1962). Economies of scale and scope in R&D, as well as the high costs and the true uncertainty in the results of R&D, are other reasons for the underinvestment. Market failure in the context of R&D is also attributable to the asymmetry of information. Government intervention targets the underinvestment in R&D in two ways. First, direct subsidies target the underinvestment directly. Complementarity of public and private funding causes the overall investment to increase more than the share of public funding. Second, incentives to collaborate focus on the causes of the gap between social and private returns (D'Aspremont & Jaquemin 1988, Kamien, Muller & Zang 1992, Miyagiwa & Ohno 2002). Benefits from collaboration are associated with increasing the scale and scope of the activities, as well as sharing of costs and risks. Collaboration also results in the companies' improved ability to handle complex innovations by different partners being endowed with complementary assets (Dodgson 1994). The latter beneficial effect of collaborations is not so much due to underinvestment in R&D; it rather relates to the R&D process directly to improve innovativeness. If direct subsidies are designed to encourage firms to engage in research collaborations, both ways of remedying market failure and increasing innovativeness can be implemented simultaneously. The overall rationale for public subsidies for R&D is summarised in hypothesis 1.

Hypothesis 1: Public subsidies have a positive impact on the generation of innovative output.

Recent empirical studies have focused on the impact of public subsidies on the generation of innovative output, as in hypothesis 1 (Almus & Czarnitzki 2003, Branstetter & Sakakibara 2002, Czarnitzky & Fier 2003).

The second step in the rationale relating to public R&D subsidies and the subsidised firms' labour demand focuses on the nexus between innovation and the labour demand. In the discussion about the influence of innovation on the firms' labour demand one has to differentiate between two types of innovations: product innovations and process innovations. Based on the contributions by Katsoulakos (1986, 1984), product innovations have a positive impact on the labour demand. Process innovations are characterised by a displacement effect in the first place, reducing the labour demand. The reduced labour demand may only be a temporary phenomenon as various compensation mechanisms can even overcompensate the initial loss of employment to yield a positive effect in the long run. The discussion about the displacement of labour and the compensating forces is about as old as economics is a science. See, for example, a good summary of the forces by Vivarelli and Petit (Petit 1995, Vivarelli 1995).

Hypothesis 2: Innovations have a positive employment effect.

Various analyses on the micro level support a positive effect of innovations on the labour demand, finding a positive net employment effect for different samples of German manufacturing firms (Entorf & Pohlmeier 1990, Rottmann & Ruschinski 1998, Smolny 1998). For a sample of UK firms, Van Reenen (1997) finds a positive net impact of innovations – as the positive effect of product innovations exceeds the negative effect of process innovations. Blanchflower and Burgess (1998) also support the hypothesis about a positive employment effect for a sample of UK and Australian firms. Positive effects of innovation on the labour demand of the innovating firms are also found for a sample of Italian manufacturing firms (Piva & Vivarelli 2002). However, the empirical evidence concerning hypothesis 2 is not unanimous. For a sample of Dutch firms, a negative relationship between innovation and labour demand is found (Brouwer, Kleinknecht & Reijnen 1993). A study of Norwegian plants reveals no clear positive relationship between innovation and employment at the plants (Klette & Forre 1998). An analysis on the industry level for a set of several European countries shows a negative net impact of product innovations and process innovations on employment (Antonucci & Pianta 2002).

The key focus of this analysis is the combination of hypothesis 1 and hypothesis 2, which poses a direct link between the public subsidies for R&D and the labour demand of the subsidised firms. Of course, public subsidies, if they enable the companies to carry out large enough projects, will have a direct positive employment effect due to the companies staffing the projects. The employment effect we are alluding to here is beyond that in terms of both timescale and scope; the employment effect relates to the project output in terms of innovation outcome rather than to the project inputs.

Hypothesis 3: Public subsidies have a significant employment effect.

Analysis relating public intervention to the innovation outcome in terms of firm growth and productivity growth can be found in various studies (Almus & Prantl 2002, Branstetter & Sakakibara 1998, Griliches & Regev 1998, Irwin & Klenow 1996, Klette, Møen & Griliches 2000, Lerner 1996). With the exception of the study by Klette and Møen, all studies find a positive impact of public intervention on the outcome variable under inspection. Yet only two studies investigate the link between public funding and labour demand (Almus & Prantl 2002, Lerner 1996). Lerner analyses the employment impact of the US small business innovation research program (SBIR) designed to stimulate innovation in small high-tech companies. He shows that subsidised firms grow at a significantly higher rate than non-subsidised firms. Almus and Prantl find a strong positive effect of public funding on the survival probability and growth of young German firms. On the plant as well as on the firm level, Maliranta shows that subsidised units contributed more to the net employment growth than non-funded units (Maliranta 2000).

The analysis in this paper finally aims at the link between public R&D subsidies and innovation output as in hypothesis 1, and the relationship between R&D subsidies and the labour demand of subsidised firms as in hypothesis 3. As hypothesis 2 does not directly relate to R&D subsidies it is not considered in the analysis in this paper, which unfolds as follows. In Section 2.2 we introduce the institutional background of the analysed subsidies. Section 2.3 starts with sketching the methodological aspects of the evaluation and eventually introduces kernel-based matching as the empirical methodology used here. In Section 2.4 we describe the data sources and the construction of the data sets. Section 2.5 contains the empirical analysis. The results relating to hypothesis 1 are reported in Section 2.5.2.1. Section 2.5.2.2 then elaborates on hypothesis 3, the impact of the public subsidy on the subsidised companies' labour demand. Section 2.6 concludes.

2.2 Institutional background of the public R&D subsidies

In the analysis we focused on subsidy programs carried out by the Finnish National Technology Agency (Tekes).[iv] The National Technology Agency has a prominent role in the Finnish national system of innovation (NSI). The two most relevant ministries in the Finnish NSI are the Ministry of Education and the Ministry of Trade and Industry. The division of labour among both is such that the universities and the Academy of Finland belong to the administrative field of the Ministry of Education. The Academy of Finland is the central body for planning and financing basic research. The National Technology Agency, however, belongs to the administrative field of the Ministry of Trade and Industry. It is the central body for planning and financing applied research and development. In 2000 Tekes' financial resources amount to 0.4 billion euros which is about 30% of the total government outlay on R&D (Tekes 2000).

Even though it might be argued that public intervention in R&D does not intend to stimulate economic growth (Georghiou & Roessner 2000), it is the legal mission of the National Technology Agency (Tekes) to promote societal welfare by means of financing the development and utilization of technology. This is laid down in the Act on the National Technology Agency 429/1993:

[The aim of the National Technology Agency is] ... to promote societal welfare and stable development by improving directly or indirectly the technological evolution and competence of industry to enhance its ability to develop internationally competitive products, processes and services ... The National

Technology Agency plans, finances, and administers R&D projects that promote the development and utilization of technology. It funds and consults in ventures aimed at the development of products, processes and services as well as promotes widespread utilization of international technological know-how and co-operation, and technology transfer. In addition, Tekes takes part in the planning of Finnish technology and innovation policies along the lines given by the [Ministry of Trade and Industry]. (Section 2 and 3 of the Act on the National Technology Agency 429/1993 translation is taken from Väänänen and Hyytinen [Väänänen & Hyytinen 2002].)

Hence we can assume that hypotheses 1 and 3 are in accordance with the targets of the Finnish National Technology Agency and the impact of the R&D subsidies can be studied on the basis of these hypotheses.

2.3 Methodology

Klette et al. note that "evaluating large-scale subsidy programs is an exercise in counterfactual analysis" (Klette, Møen & Griliches 2000). What this means and how we are analysing the counterfactual in this study will be discussed in the following sections.

2.3.1 The evaluation problem

To illustrate the evaluation problem, imagine a firm *i* can take two states, which are denoted 0 and 1. State 1 is associated with the company having undergone a certain treatment, whereas state 0 can be considered the state in which the company has not received the treatment. The treatment in our case is receiving public subsidies. The result of the company's activities in state 0 is denoted π_{i0} and the result in the state of 1 is denoted π_{i1}.

The impact of the treatment the firm receives can be given by equation (1), where Δ_i is called the *effect of the treatment on the treated*, if company *i* actually received subsidies.

$$\Delta_i = \pi_{i1} - \pi_{i0} \quad (1)^{v}$$

The evaluation problem would not exist if we could observe π_{i0} and π_{i1} at the same time. In other words, evaluation of the public subsidy program would be a trivial task if we could observe the outcome of a company's activities being subsidised and not being subsidised at the same time. Unfortunately though, in social sciences we are confronted with missing data as we cannot observe π_{i1} and π_{i0} simultaneously. For the subsidised companies we only observe π_{i1}. We do not observe π_{i0}, which is the counterfactual; it describes what would have been the situation of company *i* had it not received the subsidy. Hence the evaluation problem is a missing data problem, a solution to which can be found in estimating the missing data. The estimation, however, has to control for the selection bias that arises due to the fact that receiving a subsidy cannot be thought of as being a purely random event.

In this study we used a matching approach to estimate the counterfactual. The basic idea in this approach is to overcome the evaluation problem by estimating the counterfactual based on the *conditional independence assumption*. This assumption states that as long as the subsidised and the non-subsidised firms share the same characteristics, the counterfactual state of the subsidised companies can be estimated by the observed state of the non-subsidised companies (Rosenbaum & Rubin 1983, Rubin 1979). Once both the population of subsidized and the population of non-subsidized companies share the same characteristics, the selection bias is eliminated (Blundell & Costa Dias 2000).

This conditional independence assumption implies that the counterfactual π_{i0} of a subsidized firm *i* can be approximated by estimating the π_{k0} of a non-subsidized company *k* that is similar to company *i*. Similarity here means that the characteristics $\boldsymbol{x}_k$ of company *k* are similar to the characteristics $\boldsymbol{x}_i$ of company *i*. Hence we match a non-participating company, *k,* to the participating company, *i,* based on the observed characteristics $\boldsymbol{x}_k$ and $\boldsymbol{x}_i$. To simplify the notation and to stress the pairwise nature of the matching result we use $\boldsymbol{x}_i$ and π_i for the participating company and $\boldsymbol{x},\tilde{}_i$ and $\pi,\tilde{}_i$ for the matched, non-participating company.

The mean estimated effect $\text{mean}(\tilde{\Delta}_i)$ can then be computed from the means of the participating and the non-participating companies, as in (2).

$$\text{mean}(\tilde{\Delta}_i) = \text{mean}(\pi_i) - \text{mean}(\tilde{\pi}_i) \tag{2}$$

Various methods can be used to identify a matching company – i.e. to construct the counterfactual. An extensive overview of those approaches can be found in Heckman et al., who discuss the evaluation of active labour market programs (Heckman, Lalonde & Smith 1999).

In this study we used the kernel-based matching suggested by Heckman and collaborators (Heckman, Ichimura & Todd 1997a, Heckman, Ichimura & Todd 1997b). Czarnitzki and Fier (2003) use kernel-based matching in a set up comparable to the one presented here.

2.3.2 Kernel-based matching

Kernel-based matching estimates the counterfactual with a convex combination of all non-subsidized companies.

$$\tilde{\pi}_i = \sum_{j \in I_0} \lambda_{ij} \pi_j \text{ with } \sum_{j \in I_0} \lambda_{ij} = 1 \text{ and } i \in I_1 \tag{3}$$

$I_{1(0)}$ is the set of indices of the (non) subsidized companies. To determine the weights λ_{ij} a kernel function $K(.)$ is used.

$$\lambda_{ij} = \frac{K(d_{ij})/h}{\sum_{k \in I_o} K(d_{ik})/h} \quad i \in I_1; j \in I_0 \tag{4}$$

The kernel attaches a higher weight to company j the closer it is to company i. In (4) d_{ij} gives the distance between company i, characterised by $\boldsymbol{x}_i$, and company j, characterised by $\boldsymbol{x}_j$. The distance in the multi-dimensional space of firm characteristics is measured by the Mahalanobis metric

$$d_{ij} = (\mathbf{x}_i - \mathbf{x}_j)^t \Omega^{-1} (\mathbf{x}_i - \mathbf{x}_j), \tag{5}$$

where Ω^{-1} is the inverted covariance matrix of the matrix $\boldsymbol{X}_0$ containing all vectors $\boldsymbol{x}_j$ with $j \in I_0$. In our analysis we use the Gaussian kernel given in (6):

$$K(d_{ij}) = (2\pi)^{-0.5} e^{-0.5(d_{ij}/h)^2}, \tag{6}$$

where h is the bandwidth. Following Bergemann et al. (2001), we define h as

$$h = k(0.9n^{-0.2})^2, \tag{7}$$

where n_v and n_0 are the dimensions of $\boldsymbol{X}_0$ (Bergemann, Fitzenberger & Speckesser 2001). We use the factor δ=0.5 to scale the bandwidth.

2.4 Data

For the analysis contained in this paper we drew on various data sources.

2.4.1 Publicly subsidized R&D projects

The National Technology Agency supplied a list of companies that received research grants. The information includes the starting year of the funded research project as well as the termination year of the project.[vi] After cleaning and removal of companies due to a lack of common support with the group of non-subsidized companies we analysed 1,894 companies being funded for 2,750 projects commencing in 1994 or later.

Table 2-1. Duration of the funded projects.

1 year	2 years	3 years	4 years	5 years	6 years
15.4%	50.5%	26.8%	6.2%	0.8%	0.2%

Table 2-1 contains an overview of the distribution of the duration of the subsidized projects. More than half the projects in the analysis are of 2 years duration. About 15% start and end in the same year. Only about 7.2% of the projects are longer than 3 years.

2.4.2 Variables for evaluation

Though being aware of the various shortcomings of patent counts as R&D output indicators (Freeman & Soete 1997), we used patent applications to evaluate the impact of the subsidies, testing hypothesis 1. This output indicator is selected due to its availability, which allows us to carry out the evaluation on the basis of a rather large sample of participating companies. Furthermore, Hagedoorn and Cloodt (2003), in a comparison of potential innovation output indicators, show that patents "could be a more than acceptable indicator of innovative output". For each firm we used its number of patent applications at the National Board of Patents and Registration of Finland (NPR). Data for the years 1985 to 1999 is available. From Statistics Finland's business register we retrieved the employment of each of the companies for the time 1994 to 2000 to be able to test hypothesis 3.

2.4.2.1 Firm characteristics for matching

The firm characteristics to achieve the similarity of the matched companies capture various dimensions of the firm.

2.4.2.2 Characteristics of the companies

The characteristics of both the subsidized companies and the non-subsidized ones were drawn from Statistics Finland's business register. To characterise the firms we extracted the turnover and the employment from the business register for each year from 1994 to 2000. Both turnover and employment are used as size indicators. However, matching on both variables also makes sure that the matched companies exhibit a comparable performance in terms of labour productivity.

To ensure that companies are comparable we only matched companies with a comparable set of activities. This information is contained in the sectoral classification of the companies, which was also retrieved from Statistics Finland's business register.

2.4.2.3 Patenting history

In the matching process we have to make sure that companies are matched, i.e. show a comparable past technological performance. This is necessary to exclude the effect that a clever program administrator might have on the outcome of the impact evaluation.

To clarify this point, imagine that the internal assessment of the program within the granting organisation focuses on the technological performance of the program participants. A rational and opportunistic program administrator would then choose program participants that have exhibited a superior technological performance in the past, as they are more likely to exhibit a better technological performance in the future.

We have to exclude this effect by including a measure of the firms' past technological performance in the matching process. To approximate the level of accumulated technological knowledge and experience we computed the patent stock for each company using an annual depreciation rate of 10% p.a. The stock of patents is based on the patent counts for the years starting from 1985.

2.4.2.4 Knowledge intensity

To characterise the knowledge intensity of the firms we used data from the Finnish employment register, which enabled us to assess the number of employees in the companies with a high level of education. We regard employees with a degree from a polytechnic high school and above as having a high level of education.

2.4.2.5 Time

Concerning the time variable, we have to make sure that the subsidized company and the non-subsidized company are observed at the same point in time. Additionally, the matching also has to refer to the companies' characteristics before the subsidized projects started. Hence we matched companies on their characteristics in the year preceding the start of the project.

2.4.2.6 Constructing the data sets

Basically, we generated two different data sets containing the observations of the subsidized companies and the observations of the non-subsidized companies using the data introduced above.

The matching procedure demands that the group of non-subsidized companies is comparable to the subsidized companies. Comparability in our particular case also relates to the strategic orientation of the companies. We required both groups of companies to have a comparable strategic orientation towards innovative activities, since the subsidies only appeal to those companies. As a proxy for the strategic orientation we used the information about R&D activity contained in the R&D survey (from 1985 to 2000), the three waves of the Community Innovation Survey in Finland (1991, 1996 and 2000) and the database of Finnish innovations (Sfinno). The R&D survey, as well as the Community Innovation Survey, is conducted by Statistics Finland. The database of Finnish innovations is built and maintained by VTT Technology Studies (Palmberg, Leppalahti, Lemola & Toivonen 1999, Palmberg, Niininen, Toivanen & Wahlberg 2000)

Only companies that have reported R&D efforts at least once were included in the sample of the non-subsidized companies. The data set of the non-subsidized companies contains 83,168 observations for 11,797 companies, whereas the data set of subsidized companies contains 1,894 companies.

2.5 Empirical Analysis

In this section we present the results of the matching that allowed us to carry out the assessment of the impact of the subsidies on the innovation output and the labour demand of the subsidized firms.

2.5.1 Matching

Before matching, the sample of subsidized companies differed significantly from the sample of the non-subsidized companies. On average, the former are larger than the latter. They have a higher turnover, a larger number of employees with high education and a higher technological experience measured by the patent stock. Table 2-2 contains the population averages of the characteristics and tests for equality of means, which is rejected for any single characteristic.

Table 2-2. Sample of subsidized and non-subsidized firms before matching.

Variable	Not subsidized	Subsidized	Sig.
Employment^{+}	2.55	2.74	***
Turnover^{+}	6.57	6.77	***
High ed. empl.$^{+}$	2.45	2.70	***
Patent stock	0.11	0.21	***

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1; $^{+}$ indicates variables in logs.

The target of the matching procedure is to remove the differences and construct two comparable samples that differ only in the fact that one sample contains the subsidized firms and the other one contains non-subsidized firms. Then, the differences in the observed patenting and employment are only caused by the subsidy, rather than by the different composition of the sets of companies.

We conducted the kernel-based matching discussed in Section 2.3.2 using the firms' characteristics such as employment, turnover, highly educated employment and patent stock. Additionally, we controlled for the time variable and the sector of firms' activity. The matching was performed on the characteristics of the companies in the year before the project started.

Table 2-3 summarises the sample of subsidized and non-subsidized companies after the matching. Now we cannot reject the equality of means.

Table 2-3. Sample of subsidized and non-subsidized firms after matching.

Variable	Not subsidized	Subsidized	Sig.
Employment^{+}	2.71	2.74	
Turnover^{+}	6.74	6.77	
High ed. empl.$^{+}$	2.68	2.70	
Patent stock	0.21	0.21	

Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1; $^{+}$ indicates variables in logs.

2.5.2 Impact analysis of the program

In the following sections we will discuss the impact of the public subsidies on the innovative output in terms of patenting. Eventually, we will discuss the impact of public subsidies on the development of the labour demand of the companies.

The feature that the subsidy program is directed to R&D projects means that there is no single point in time that can be referred to as a reference. Rather, we have to observe the development of the innovation output and the labour demand over time. We analysed the patenting behaviour during the project, the results referring to this time interval are labelled *during project*. Some of the patents – being research results of the project – are filed after the project ends. In the following evaluation the patents being filed in the year after the project ends are accounted for and labelled *after project*. The results labelled *total* combine both the patents during the project as well as after the project.

The potential employment impact of the project sets in with a time lag that cannot be specified a priory. Therefore, we observed the employment record of the companies over a period of 4 years after the firm started to receive funding.

2.5.2.1 Effect on patenting

We evaluated the effect of the public subsidy in terms of the average patenting behaviour of the group of subsidized and non-subsidized firms. To eliminate both time-invariant individual effects and common time effects that affect both the subsidized and the non-subsidized firms, we focused on the difference-in-difference – i.e. the difference in annual patent output after or during the project compared with the patenting output before the project (Blundell & Costa Dias 2000, Jaffe 2002). Hence, in combination with the matching approach, we estimated the effect by means of a conditional difference-in-difference approach.

Table 2-4 reports the average change in patenting for both groups and a significance indicator of the t-test testing for the equality of the means. The availability of the patenting data required that we restrict the sample to projects that terminated in 1999 or earlier for the measurement of the effect during the project. For the estimation of the total and the after-project impact, we had to restrict the sample to projects that ended in 1998 or earlier. The sample size is also reported.

Table 2-4. Overall impact of the program.

	Patenting	N	Not subsidized (I)	Subsidized (II)	Sig
(i)	Total	483	–0.0198	0.0154	.
(ii)	During project	858	–0.0153	0.0410	**
(iii)	After project	483	–0.0345	0.0248	.

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1. Column (I) and column (II) contain the average change in patenting per year, where the patenting in the year before the project is the reference.

We observed that had the companies not been subsidized companies they would have reduced their average annual patenting over time. At the same time, however, the subsidized companies experienced an increase in average annual patenting activity. The average level of patenting for a subsidised firm during the project is 0.04 patents per project per year higher than the level of patenting in the year preceding the funding. Had the company not been funded the level during the same period of time would have been 0.015 patents per project per year lower than in the reference year. Table 2-4 shows a significant positive effect as the average change in patenting is higher with subsidies than it would have been had the subsidized companies not been subsidized. Hence, hypothesis 1 is supported by our findings.

As illustrated in Table 2-1, the subsidized projects are of different durations. A detailed analysis of the effect accounting for the differing durations seems mandated. Table 2-5 shows the total impact of the projects broken down for project durations of one to four years. The impact of projects that had not terminated by 1998 cannot be assessed fully as the latest available patent information dates from 1999. For each project duration we give the latest possible start year of the projects in the column labelled *Start*.

We observed a positive impact of the subsidy for any project length. The impact for the two-year projects is significant, although the impact for the one and three-year projects is only mildly so. The four-year projects also turn out not to be of significant impact, although the absolute value of the average change in patenting per year would suggest otherwise. The significance level could be caused by the small number of observations that are included in the analysis.

Table 2-5. Project duration and impacts.

Duration	N	Start	Not subsidized(I)	Subsidized (II)	Sig.
1 year	193	...1998	–0.0420	0.0103	.
2 years	472	...1997	–0.0290	0.0240	*
3 years	158	...1996	–0.0127	0.0870	.
4 years	35	...1995	–0.0063	0.3142	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1. Column (I) and column (II) contain the average change in patenting per year, where the patenting in the year before the project is the reference.

Summarising the analysis up to this point, we observed support for the hypothesis that public R&D subsidies have a positive impact on the generation of innovation output.

2.5.2.2 Effect on labour demand

To investigate the impact of the public subsidies on the labour demand of firms we have to be guided by two considerations. First, previous studies have established a considerable time lag between the introduction of an innovation and its subsequent impact on the labour demand. As patenting is associated with the invention stage rather than with the innovation stage, we can expect an even longer time lag. Second, as we only established the most significant positive effect for two-year projects, we should only base our further investigation on those projects.

Additionally, we restricted the sample to the projects starting in the year 1996. The two-year projects ended in 1997. The availability of the employment data up to the year 2000 allows investigating the impact up to three years after the project ends. Before turning to the analysis of the employment effect, we have to investigate two prerequisites:

First, the matching procedure above produces a sample of subsidized firms and a sample of non-subsidized firms that are corrected for selection bias. This feature does not necessarily translate into the smaller subsample being investigated now. The upper part in Table 2-6 reveals that even for the subsample of two-year projects started in the year 1996 the matching generated comparable samples of subsidized and non-subsidized companies. Testing for the equality of the averages of the firm characteristics used for matching does not reject the equality.

Table 2-6. Employment effect.

Variable	Year	Non subsidized	Subsidized	Sig.
Employment[+]	1995	2.64	2.68	
Turnover[+]	1995	6.87	6.84	
High ed. empl.[+]	1995	2.36	2.39	
Patent stock	1995	0.15	0.16	
Patenting change	1995–1998	–0.0197	0.0347	
Empl. growth	1994–1995	–0.0874	–0.1160	
Empl. growth	1996–1997	0.1072	0.1343	
Empl. growth	1996–1998	0.0492	0.1090	
Empl. growth	1996–1999	–0.0036	0.0759	.
Empl. growth	1996–2000	–0.0890	0.0366	**

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 The effects given here do only refer to the 2-years projects starting in 1996.

Although the matching characteristics are comparable in the samples, subsidized companies show a higher patenting activity compared with the non-subsidized companies. The subsidies for the two-year projects starting in 1996 have a positive impact on the generation of innovative output, as the change in patenting is higher for the subsidized group than for the control group. This impact is not significant at the 10% level though.

Fundamentally, the analysis here looks at differences in the mean of some characteristics of the sample of subsidized and the sample of non-subsidized firms. We deduce an impact if there is no difference in the mean of some characteristic before the public funding but there is a significant difference in the characteristics after or during the public funding. This brings us to the second prerequisite. We can only deduce an employment effect if, and only if, the employment variable before the public subsidized projects do not differ. Table 2-6 reveals that, on average, the companies in both samples experienced a reducing level of employment in the years 1994 to 1995, which does not differ significantly between the group of subsidized companies and the group of non-subsidized companies. Even though the employment growth is not a characteristic used in the matching process, the matching still manages to create samples that do not differ in terms of employment growth before the R&D subsidy.

When assessing the labour demand effect of public R&D subsidies we have to investigate the development of the employment during the project and after the project. During the project the employment growth rates do not differ significantly between the samples of subsidized and non-subsidized companies. After the project, however, we experience a positive, but declining average employment growth rate in the sample of subsidized companies; in the sample of non-subsidized companies we see a negative and declining average growth rate of employment. The differences are significant for the average annual employment growth rates for the time from 1996 to 1999 and to 2000.

As the sample of subsidized companies and the sample of non-subsidized companies are comparable according to the chosen characteristics and, furthermore, do not exhibit differential employment growth prior to being subsidized, we can attribute the observed differential growth in employment to the public funding. This finding supports hypothesis 3 and establishes a positive impact of the R&D subsidies on the labour demand of the subsidized companies.

2.5.2.3 Results from a balanced panel

The results in the previous section suggest a positive impact of R&D funding on the employment growth of companies. Recall, however, that the data source used in the analysis is an unbalanced panel; it contains entries and exits.

Although an exit of a company represents the most severe development in employment, we wanted to eliminate the effect of exit on the results of the previous section to get an idea about the sources of the superior growth performance of the subsidised companies. Table 2-7 and Table 2-8 contain the analysis for a balanced sample of companies. All companies that exited in the years 1996 to 2000 are eliminated from the data set. Note that the analysis of the balanced panel grossly underestimates the real effects; it was carried out to eliminate the effects exiting companies have on the assessment of the employment growth impact of the innovations.

Table 2-7. Overall impact of the program – balanced panel.

	Patenting	N	Not subsidized (I)	Subsidized (II)	Sig
(i)	Total	307	0.0012	0.0162	
(ii)	During project	562	0.0031	0.0279	
(iii)	After project	307	–0.0060	0.0390	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1. Column (I) and column (II) contain the average change in patenting per year, where the patenting in the year before the project is the reference.

Although the results in the case of the balanced panel show qualitatively the same picture, they are not significant for most steps of the analysis. The final assessment of the employment growth impact of public R&D subsidies as displayed in the bottom row of Table 2-8 remains still significant at the 10% level. The favourable impact of R&D subsidies can even be observed when company death is eliminated from the data.

Table 2-8. Overall impact of the program – balanced panel.

Variable	Year	Non subsidized	Subsidized	Sig
Employment^{+}	1995	2.99	3.03	
Turnover^{+}	1995	7.06	7.10	
High ed. Empl.$^{+}$	1995	2.72	2.73	
Patent stock	1995	0.16	0.16	
Total patenting	1996–1998	0.0585	0.0877	
Empl. growth	1994–1995	–0.0849	–0.1300	
Empl. growth	1996–1997	0.0398	0.1100	
Empl. growth	1996–1998	0.0525	0.1228	
Empl. growth	1996–1999	0.0715	0.0986	
Empl. growth	1996–2000	0.0055	0.0773	.

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 The effects given here do only refer to the 2-years projects starting in 1996.

The results of the differences between the unbalanced panel and the balanced panel exercise suggest that R&D subsidies have an impact on the companies' exit from the business register. Ebersberger (2004b) presents an analysis of the impact R&D subsidies have on the companies vanishing from the business register. The plausibility considerations there lead to the classification of the unobservable event giving rise to the companies' vanishing from the business register. Exit (going out of business) and acquisition are distinguished. The overall result of the exercise is that R&D subsidies have a strong negative impact on the companies' likelihood to be acquired. Burdened with financial constraints, the receipt of R&D subsidies ensures the companies' independence, especially in the early stage of large R&D projects. On the other hand, R&D subsidies do not affect the companies' probability to exit in the same magnitude as they influence the probability to be acquired.

2.6 Conclusion

In this analysis we investigated the innovation output and the employment effect of public subsidies for innovation. We used a sample of Finnish companies receiving subsidies for their innovative efforts. We matched those companies with companies that never received any subsidy for R&D. The results of our study support the hypothesis that public subsidies have a positive impact on the innovative output of companies. We also established an empirical link between the funding and the companies' subsequent labour demand. Public subsidies for innovation are found to have a positive influence on the companies' employment growth.

The positive impact of the policy of direct involvement through R&D funding can be attributed to three facts. First, there is an incentive for firms to collaborate built into the funding criteria of the National Technology Agency (Schienstock & Hämäläinen 2001). Empirical evidence suggests that this incentive increases the companies' propensity to collaborate for innovation. Second, although there are generally some conflicting results concerning the complementarity of public and private R&D spending (David, Hall & Toole 2000), studies for Finland suggest complementarity of public R&D subsidies and private investment in R&D (Ali-Yrkkö & Pajarinen 2003, Lehto 2000). Therefore, public R&D subsidies lead to an increase in nominal R&D inputs. Finally, the increased resources for R&D do not face an inelastic labour supply for engineers and scientists in Finland as the Finnish innovation system has been able to constantly increase the supply of science and technology graduates (Georghiou, Smith, Toivanen & Ylä-Anttila 2003). The increased resources for R&D do not translate into rising wages for engineers and scientists; rather, they increase the real input in R&D.

As the subsidy program directly targeted the R&D activities of the subsidized firms, we could evaluate the impact of the program in terms of R&D output and labour demand. The mere focus on the effects of the program and the neglect of the magnitude of the resources spent on the program puts the effectiveness rather than the efficiency of the program on the central stage of our study.

An additional result has been derived which indicates that although the direct project support for firms is a subsidy it does not interfere with the market as a selection mechanism. R&D subsidies are found to have a small (if any) impact on the companies' survival if we distinguish exit and the subsidised company being acquired. R&D subsidies tend not to prevent companies from exiting; rather, they support the companies' independence. R&D subsidies are found to have a positive impact on the competitive situation in an industry as support for the companies' independence has a positive bearing on the concentration in the respective industry, also maintaining the industries' internal heterogeneity. Yet, from an innovation efficiency point of view we cannot convincingly argue that this effect of R&D subsidies is beneficial, as it could very well be the case that innovation is more efficiently generated in large companies (Schumpeter Mark II).

3. Collaboration

The discussion presented here draws on results discussed in Ebersberger and Lehtoranta (2003), Dachs, Ebersberger and Pyka (2004), Ebersberger (2004c). The analysis presented here basically considers two questions. First, we investigate the collaboration with knowledge-intensive services for innovation. Second we investigate the change in motives for collaboration over time.

3.1 Use of knowledge-intensive services

Two observations motivated this analysis. First, it has been argued that it has become increasingly difficult for firms to innovate alone. A number of relationships, internally within the innovating firm as well as externally with partners outside the firm, are essential for successful innovation. Not only in high-tech industries are collaboration and joint research ventures important ingredients for successful innovation, it has also become an integral part of the innovation strategy for firms in the low-technology sectors to involve outside actors in the innovation process (see e.g. Palmberg 2001).

Second, manufacturing and services are becoming more and more interwoven. This can be attributed to two trends we have observed. The first trend is that corporate innovation strategies are stressing the service content of their new products associated with the de-materialisation of the products and the production processes. New business models follow slogans such as "from products to services". The second trend is that services are playing an increasing role in the generation of new products. According to den Hertog et al. (1997), more than four-fifths of the value added in manufacturing occurs due to service activities. Recently, the importance of interaction with knowledge-intensive services has been emphasised (e.g. Müller & Zenker 2001, Czarnitzki & Spielkamp 2000, Strambach 2001). In this research we focus the increasing interrelatedness of manufacturing and services manifested by the increasing role knowledge-intensive services are playing in the innovation activities of firms.

When discussing the contribution of knowledge-intensive services to the innovation process, their bridging function (Czarnitzki & Spielkamp 2000) or their participation in the knowledge distribution and their role in the moderation of the knowledge flow has to be considered (e.g. Hauknes 1998). Hauknes stresses the growing importance of the role of knowledge-intensive services in innovation when he points out that "the generation and diffusion of innovations rely more and more upon new technological knowledge which is generated not only by learning processes implemented by internal research and development laboratories, but also and to a growing extent, by the daily interaction, communication and trading of information of learning firms among themselves and with other scientific institutions. KIBS firms play a major role in this context as qualified interfaces. KIBS firms in fact act more and more as bridges and converters between technological and business expertise and localised knowledge and capabilities, becoming problem-solving actors specialised in the provision of the complementary knowledge inputs allowing the generation of innovations." (Hauknes 1998, p. 5.)

Various definitions of knowledge-intensive service activities (KISA)[vii] are maintained in the literature. For example: "KIBS can be described as firms performing, mainly for other firms, services encompassing a high intellectual value-added" (Müller 2001, p. 2); Czarnitzki and Spielkamp (2000) use the industrial classification to distinguish knowledge-intensive services from other services and describe them as a "bridge to innovation"; Miles et al. (1995) define knowledge-intensive business services as "services [which] rely heavily upon professional knowledge, and either supply products which are themselves primarily sources of information and knowledge to their users, or use their knowledge to produce services which are intermediate inputs to their clients' own knowledge generating and information processing activities, having other businesses as their main clients."

As no clear-cut and universally accepted definition of knowledge-intensive service activities is available, we use a rather broad definition for this research. We define knowledge-intensive services as services that are *innovation services provided either internally or externally to a firm or an organisation*, where *innovation services* are understood as services targeted towards the development of an organisation and its patterns and objectives of innovation. By this definition, public and not-for-profit research institutes are also considered to be knowledge-intensive services. So are universities. Consulting companies are also consistent with the notion of knowledge-intensive services here. So, our definition here goes beyond the pure corporate and business dimension brought forth by Müller (2001) and Czarnitzki and Spielkamp (2000). Our definition strongly hinges on the interaction between the knowledge-intensive services and the innovating company. Hence, it references the observations in Hauknes (1998).

In this paper we analyse the relevance of the interaction between innovating companies and knowledge-intensive services in Finland. In particular, we focus our attention on the traditional manufacturing industries and companies in the forest cluster. These are firms from NACE classes 20 (Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials), 21 (Manufacture of pulp, paper and paper products) and 361 (Manufacture of furniture). This concentration is in part a reflection of the theoretical discussion within the systems of innovation literature[viii], which has been extended towards the notion of sectoral systems of innovation (cf. Breschi & Malerba 1997, Malerba 2002). Considering the size of the forest cluster within the Finnish economy and its prominent role in the technological funding schemes, the focus on the forest cluster is also a reflection of the economic reality.[ix]

3.1.1 Research questions

The notion of systems of innovation, and the refinement to sectoral systems in particular, strongly emphasises the interaction between different actors in shaping the innovation capability of each single actor in the system. Actors do not collaborate because they are equal, they co-operate for innovation because they are heterogeneous. Co-operation is a channel for making available and exchanging complementary assets, knowledge and capabilities. Hence the story about co-operation for innovation is a story about sharing. As the evolutionary strand of the literature stresses the heterogeneity of the actors, collaboration is about sharing assets, capabilities and knowledge. So, learning and knowledge accumulation is an integral motive for and part of the co-operation (Nelson & Winter 1982, Malerba 1992, Pyka 1999, 2000). The first question in this context is about the **role and the magnitude of interaction** with knowledge-intensive services in traditional industries, and in the forest cluster in particular.

Besides a formal mode of interaction, such as joint R&D ventures, collaborations or the establishing of technological standards, interaction may also include more informal practices, such as reverse engineering and information exchange networks among engineers and scientists (see e.g. Foray 1995). Reverse engineering can be understood as the involuntary leaking of new technical information involving only a one-way flow of information (Pyka 1997). Informal communication in networks, however, consists of mutual and voluntary information exchange. In formal networks such as R&D collaboration contractual agreements are the very basis of the information exchange. Yet the contractual agreements are burdened with problems, such as intrinsic uncertainty of innovation processes or moral hazard of the participating actors. In terms of transaction costs, informal relationships seem to have the advantage of being simple, uncomplicated and, therefore, less expensive concerning co-ordination efforts. This brief discussion suggests that in the analysis we should **distinguish between formal and informal** interaction.

Regardless of whether companies interact with the knowledge-intensive services formally or informally, the notion of collective innovation suggests that different types of partners are required for successful innovation (Allen 1983). However, the sheer number of different partners is not the whole story. Laursen and Salter (2004) discuss search strategies for innovation. They characterise the number of different types of knowledge sources as *breadth*. We argue that this notion is not only applicable to sources of knowledge for innovation, it also applies to interaction. They also stress that the *depth* of search matters, where their notion of depth relates to the intensity or the assessed value of the knowledge source. This notion, we would argue, also applies to interaction, where depth denotes the intensity of interaction within the chosen portfolio of the interaction partners. Both **breadth and depth of interaction** has to be analysed below. The notion of depth leads us to the analysis of the **evaluation of the impact** of the interaction captured by the perceived value the interacting firm assigns to the interaction.

The systems of innovation discussion also stresses that it is not only private actors shaping the system. State involvement also plays a crucial role. The involvement of the State is analysed below in two different features. First, we distinguish the knowledge-intensive services based on their being offered by **public or private organisations**. Second, we analyse the **influence of public R&D funding** on both the breadth and the depth in the usage of knowledge-intensive service activities. The latter analysis is inspired by the fact that the

Finnish collaboration culture, to a large part, has been established by linking R&D subsidies with the requirement to collaborate.

3.1.2 Structure of the analysis

By and large, the analysis is empirical and explorative. It draws on two distinctively different data sets. The first data set used for this study is the Community Innovations Survey (CIS), to be described in more detail in the discussion below. The distinctive feature of the innovation survey is that it focuses on the innovating firm; it follows the subject approach. The second data source utilised in this exercise is the database of Finnish innovations (Sfinno), which focuses on the innovation itself; it follows the object approach. A combination of both data sets allows us to shed some light on the relevance of knowledge-intensive services for innovation in traditional industries.

The analysis unfolds as follows. Section 2 presents the analysis of the firm-level data. The analysis of the innovation-level data is discussed in Section 3. Section 4 concludes.

3.1.3 Firm-level analysis

The analysis in the following section investigates the role and importance of knowledge-intensive services within the firms' innovation activities. We particularly focus on certain actors, which can be subsumed under our rather broad definition of knowledge-intensive services. These actors include universities, private and public research institutes, and consulting companies. The importance of the actors is measured by the fraction of companies involving the respective partner in collaborative innovation activities. Additionally, we analyse the subjective importance of the role those partners play for firms.

The analysis distinguishes between service companies and manufacturing companies. Within the manufacturing we differentiate between traditional sectors, combining the low-technology manufacturing sectors, as well as the low to medium technology manufacturing (Hatzichronoglou 1997). The traditional sectors are split up in companies belonging to the forest cluster, defined by the NACE industrial classes 20, 21 and 361.

3.1.3.1 Data

The data set used in this exercise is taken from the third wave of the Community Innovation Survey. This survey was implemented in 2001 and is based on the core Eurostat Community Innovation Survey (CIS) questionnaire. The method and types of questions used in this innovation survey are described in the OECD's Olso Manual (OECD 1997). CIS data are increasingly being used as a key data source in the study of innovation at the firm level in Europe. CIS surveys are usually conducted every five years. They are often denoted as following the 'subject-oriented' approach because they ask individual firms directly about innovative activities and innovation results, such as product innovations or process innovations. Furthermore, the CIS surveys various characteristics of the firm relating to the innovation processes. The questionnaire also asks the individual firms to assess the value of certain influences in their innovation process, such as the value of certain collaboration partners or knowledge sources. Ever since the CIS was first launched in the early 1990s it has been widely piloted and tested before implementation.

The CIS questionnaire itself is based on previous generations of innovation research, including the Yale survey and the SPRU innovation database (Klevorick et al. 1995, Pavitt, Robson & Townsend 1987). It provides an opportunity to investigate patterns of innovation across a large number of industrial firms. It also enables researchers to explore the relationship between indicators of performance and different strategies for innovating (see e.g. Dachs, Ebersberger & Pyka 2004, Cassiman & Veugelers 2002). Although imperfect, the CIS data does provide a useful complement to the traditional measures of innovation, such as patent statistics. Compared with R&D and patent data, innovation output indicators in the CIS have the advantage of measuring innovation directly (Kleinknecht et al. 2002).

The Finnish innovation survey, which is the data basis for the analysis in this section, was conducted by Statistics Finland. The questionnaire was sent to 3,462 companies, 50% of whom replied (Statistics Finland 2002a). The inclusion of sampling weights allows for extrapolating the analysis to the whole economy.

3.1.3.2 Results

This section gives a brief overview of the results of the analysis. First, we investigate the innovation activities and the collaboration pattern across the sectoral breakdown sketched above. The analysis in the following sections draws on the five following items surveyed by the CIS.[x]

1. Companies are asked to state whether they had co-operation arrangements for R&D.[xi] If so, they are to indicate the co-operation partners. Amongst others, companies are asked to differentiate between (i) universities, (ii) commercial laboratories or R&D enterprises, (iii) government or non-profit research institutes, and (iv) consultants.

2. Companies are also asked to assess the importance of the co-operation partner on a 0 to 3 Likert scale.

3. Additionally, the sources of information for innovation are inquired. Amongst others, companies can indicate the importance of (i) universities, or (ii) governmental or private non-profit research institutes on a 0 to 3 Likert scale. In this question 0 means that the source is not used.

4. Companies are asked whether or not they received governmental funding for their innovation activities.

5. Companies are to indicate whether or not they

   a. introduced new or significantly new products to the market
   b. introduced new or significantly new production processes
   c. had ongoing or abandoned R&D projects.

We talk about a company showing innovative activities or being an innovator if it reported a product innovation, a process innovation, an ongoing or an abandoned innovation project. Collaborative companies are companies that have indicated collaboration regardless of the type of partner.

3.1.3.2.1 Innovation activities and collaboration in general

Table 3-1 depicts the propensity to conduct innovative activities in the first column, the frequency to collaborate among all firms in the second column and the frequency to collaborate only among innovators in the third column. As expected, the likelihood of innovation activities is higher in the manufacturing sectors than in the service sectors. Within the manufacturing sector the frequency of innovation activities increases with the knowledge-intensity of the sectors. The sub-sample of companies from the traditional sectors subsuming the low-technology manufacturing and the medium-low-technology manufacturing (see Hatzichronoglou [1997] for a definition) contains 45.1% of companies with innovation activities. The other manufacturing sectors, consisting of the high-technology manufacturing sector as well as the medium-high-technology manufacturing sectors, show a significantly higher share of companies with innovation activities. Companies from the forest cluster, however, do not differ from companies in the other traditional sectors.

If we examine the sheer proportion of companies with innovation collaboration, we can draw the same picture as in the case of innovation activities. However, this result may be distorted by the fact that only innovators collaborate for innovation. Having accounted for this fact in the third column of Table 3-1, we observe that the difference in collaboration behaviour between the service sectors and the manufacturing sectors vanishes, but the difference within the manufacturing sectors still remains. The propensity to collaborate for innovation increases with the technology intensity.

Companies receiving public funding for R&D exhibit a higher propensity to collaborate than companies that do not receive public funding. We tend to argue that the causation runs from public funding to collaboration rather than the other way round. Public funding succeeds in promoting and fostering collaboration. The findings here are in accordance with the findings in Dachs et al. (2004) and the prevailing funding schemes in Finland. Public funding is intended to foster collaboration for innovation. The funding schemes hence succeed in influencing the collaborative behaviour of firms.

Table 3-1. Innovation activity and collaboration.

	Innovation activities		Collaboration		Collaboration (innovators only)	
All companies						
Services	0.383		0.187		0.488	
Manufacturing	0.493	***	0.255	***	0.517	
Other Manufacturing	0.608		0.373		0.614	
Traditional Sectors	0.451	***	0.212	***	0.470	***
Other Traditional Sectors	0.448		0.217		0.485	
Forest Cluster	0.462		0.190		0.410	
Traditional sectors						
No public funding	-		0.120		0.364	
Public funding	-		0.627	***	0.627	***
Forest cluster						
No public funding	-		0.107		0.320	
Public funding	-		0.537	***	0.537	*

3.1.3.2.2 Formal interaction

As discussed above, the interaction between the knowledge-intensive services and the innovating company can either be formal or informal. The CIS data sets cover the formal interactions as they ask the innovating firms about their collaborative relationships concerning R&D. Table 3-2 and 3-3 display the analysis of the formal interaction between innovating companies and the knowledge-intensive service providers. We analyse the public sector first before we turn to the discussion of the private sector.

Public sector knowledge-intensive services

The public sector providers of knowledge-intensive services covered in the Community Innovation Survey are universities and governmental research institutes. Table 3-2 on page 55 shows the importance of collaboration with universities for innovation. Disregarding the firms' status in innovation activities, manufacturing firms are seen to have more frequent collaboration with universities than service firms. Within the manufacturing sectors, companies from the traditional sectors as defined above prove to be less frequently co-operating with universities. Yet there is no significant difference in collaboration between firms from the forest cluster and firms from other traditional sectors. When restricting the sample to only innovating companies, the difference between firms in the service sectors and firms in the manufacturing sectors vanishes. Innovating service firms and innovating manufacturing firms exhibit an equal propensity to collaborate with universities. The difference between the traditional sectors and the high and medium-high-technology sectors persists even if we only look at innovating companies.

Regardless of whether they collaborated with universities or not, companies from the traditional sectors value the collaboration with universities as less important[xii] than companies from the high and medium-high-technology sectors. Interestingly, this differential valuation disappears if we assess the valuation of the companies that collaborated with universities. Although there may be a selection bias in that companies that *a priori* assess the collaboration with universities as more important have a higher propensity to collaborate. However, we tend to interpret the result in the way that the true value of the collaboration reveals itself through co-operation.

Firms from the forest cluster that pursued co-operative R&D with universities tend to value this partner higher than other companies in the traditional sectors. Note that although being higher than in the other firms of the traditional sectors, the appreciation of the university collaboration in the forest cluster is approximately as high as in manufacturing. Still, it is lower than in the high and medium-high-technology manufacturing.

The pattern of collaboration with governmental research institutes resembles the collaboration with universities, although the absolute level of collaboration is considerably lower. Take for example the collaboration of innovating manufacturing companies: 39.8% of all innovative manufacturing companies collaborate with universities for innovation; only 24.9% collaborate with governmental research institutes. Astonishingly, the assessment of the importance of governmental research institutes among companies being involved in co-operative R&D with research institutes is significantly lower among firms from the forest cluster than in companies from other traditional sectors. Close inspection of the sectoral decomposition reveals that the high average valuation in the other traditional sectors is based on the firms from the

NACE 15 (food products, beverages and tobacco), NACE 28 (fabricated metal products) and NACE 35 (transport equipment) classes.

Up to this point the discussion suggests that the knowledge-intensive services provided by the public sector are of considerable importance for innovating companies from the forest cluster: about 37.7% of the companies that have been involved in collaborative research with governmental research institutes report that the collaboration was of high or significant importance. For universities, the assessment is even more favourable: 53.4% of the firms having collaborative experience with universities assess the collaboration as being of high or significant importance.

Private sector knowledge-intensive services

The knowledge-intensive business services from the private sector covered in the CIS survey are private sector research institutes and consulting companies. Table 3-3 on page 56 reports the results of the analysis for the knowledge-intensive services from the private sector. We find comparable collaboration patterns for both partners. Collaboration is more frequent in the manufacturing sectors. Within the manufacturing sectors the collaboration frequency in the traditional sectors are about half the frequency in the high and medium-high-technology sectors.

Once we account for the differences in the propensity to innovate across sectors we find no difference in the frequency to collaborate with commercial research facilities or with consulting companies between the average innovating company and the average manufacturing company. Still, companies from the traditional sectors formally interact less frequently with private sector KISA providers than the high and medium-high-technology companies do. The common assessment of the importance of private knowledge-intensive services does not differ across the analysed sectors. However, the assessment of the importance judged by the companies that have collaborative experience with the partners reveals a remarkable difference. The sectors do not differ in their assessment of the importance of formal interaction with private research organisations for their innovative activities. Yet in the forest cluster we observe a strong statement in favour of the importance of the collaboration with consulting companies for the innovation activities: more than 72% of the companies with collaborative experience state that the collaboration is of significant or high importance for their innovation activities.

Generally, the knowledge-intensive service providers from the private sector receive quite a high valuation of their services for the innovative activities: about 60% of the collaborating companies report high or significant importance of collaboration with private research organisations for their innovative activities.

Table 3-2. Knowledge-intensive services from the public sector.

	Collaboration		Collaboration (innovators only)		Assessment of the collaboration (innovators only)		Assessment of the collaboration (collaborators only)	
Universities								
Services	0.099		0.259		0.175		0.675	
Manufacturing	0.153	***	0.311		0.168		0.541	
Other Manufacturing	0.242		0.398		0.255		0.640	
Traditional Sectors	0.121	***	0.268	***	0.125	***	0.468	
Other Traditional Sectors	0.128		0.285		0.130		0.456	
Forest Cluster	0.093		0.201		0.107		0.534	*
Governmental res. institutes								
Services	0.080		0.210		0.097		0.462	
Manufacturing	0.091		0.185		0.110		0.593	
Other Manufacturing	0.151		0.249		0.123		0.493	
Traditional Sectors	0.069	***	0.154	**	0.104		0.673	*
Other Traditional Sectors	0.071		0.157		0.117		0.742	
Forest Cluster	0.065		0.141		0.053	*	0.377	**

Note: Traditional sectors consist of the low-technology manufacturing and the low to medium technology manufacturing. The forest cluster is represented by firms from the NACE classes 20, 21 and 361. The numbers give the fraction of companies with the respective characteristic extrapolated to the level of the Finnish economy. *** (**, *) indicates a significance level of 1% (5%, 10%).

Table 3-3. Knowledge-intensive services from the private sector.

	Collaboration		Collaboration (innovators only)		Assessment of the collaboration (innovators only)	Assessment of the collaboration (collaborators only)	
Private research facilities							
Services	0.066		0.171		0.116	0.675	
Manufacturing	0.097	*	0.196		0.123	0.624	
Other Manufacturing	0.158		0.260		0.156	0.600	
Traditional Sectors	0.074	***	0.165	**	0.106	0.642	
Other Traditional Sectors	0.078		0.174		0.116	0.666	
Forest Cluster	0.061		0.131		0.068	0.523	
Consulting companies							
Services	0.070		0.183		0.102	0.557	
Manufacturing	0.117	***	0.236		0.118	0.501	
Other Manufacturing	0.180		0.296		0.132	0.446	
Traditional Sectors	0.093	***	0.207	**	0.112	0.539	
Other Traditional Sectors	0.093		0.207		0.102	0.492	
Forest Cluster	0.096		0.207		0.150	0.724	*

Note: Traditional sectors consist of the low-technology manufacturing and the low to medium technology manufacturing. The forest cluster is represented by firms from the NACE classes 20, 21 and 361. The numbers give the fraction of companies with the respective characteristic extrapolated to the level of the Finnish economy. *** (**, *) indicates a significance level of 1% (5%, 10%).

Table 3-4. Depth and breadth of the search strategy.

	Breadth of collaboration (collaborators only)		Depth of collaboration (collaborators only)	
All companies				
Services	0.823		1.003	
Manufacturing	0.929		1.003	
Other Manufacturing	1.204		1.084	
Traditional Sectors	0.794	***	0.951	
Other Traditional Sectors	0.824		0.957	
Forest Cluster	0.679		0.923	
Manufacturing				
No public funding	0.495		0.524	
Public funding	1.438	***	1.330	***
Traditional sectors				
No public funding	0.484		0.528	
Public funding	1.257	***	1.318	***
Forest Cluster				
No public funding	0.322		0.506	
Public funding	1.185	***	1.274	**

Note: Traditional sectors consist of the low-technology manufacturing and the low to medium technology manufacturing. The forest cluster is represented by firms from the NACE classes 20, 21 and 361. Breadth and depth is evaluated only for companies that collaborated with at least one of the partners given in the survey. *** (**, *) indicates a significance level of 1% (5%, 10%).

Breadth and depth of collaborative behaviour

The breadth of the formal interaction between innovating companies and the knowledge-intensive services is approximated in this analysis by the number of different types of partners the collaborating company co-operated with.

Table 3-4 on page 57 displays the average breadth of the formal interaction. By and large, there are no differences in the breadth of the interaction between services and manufacturing. Within manufacturing, however, we find high-technology manufacturing and high to medium-technology manufacturing firms maintaining broader interaction than companies from the traditional sectors do. Distinguishing the traditional sectors in firms from the forest cluster and other firms does not lead to significant differences.

The depth of the interaction is approximated here by the number of collaboration partner types that are considered to be important. There we find that, on average, there is no difference within the sectors.

However, statistically significant differences do show up if we distinguish the sectors further into companies that received public funding for R&D and companies that did not. Publicly funded companies turn out to maintain significantly broader and deeper interactions than companies that do not receive public funding. Implying a causal link that goes from public subsidies to the pattern of collaboration, we can interpret this finding as supporting the effectiveness of the public subsidies schemes in inducing collaboration. It seems that not only the size of the network is influenced by public funding but also the quality of collaboration is affected positively. This finding is in accordance with prior findings, such as Dachs et al. (2004).

3.1.3.2.3 Informal interaction

The informal interaction between innovators and knowledge-intensive services can only be approximated by the question in the innovation survey inquiring about the importance of certain knowledge sources for the innovation activity.[xiii] Contrary to the collaboration question, the question about the information sources does not explicitly refer to formal relationships or arrangements. This particular difference in the formulation of the question is utilised here to approximate informal interaction. Companies that reported using universities or governmental research institutes as a source of knowledge, but which, at the same time, did not report formal collaboration, are classified as being interacting informally.

Table 3-5 on page 60 shows the results of the analysis of the informal interaction. Across the different sub-samples we do not observe a significantly different propensity to engage in informal interaction with universities and governmental research institutes. However, we do observe a strong difference in the valuation of universities as knowledge sources for informally interacting companies from the forest cluster; only about 5% of the companies state that universities are a large or significant knowledge source, whereas about 25% of the companies from other traditional sectors attribute large or significant importance to the universities as a knowledge source for innovation. Concerning the governmental research institutes, we find a slightly positive difference in the valuation between manufacturing firms and service firms, where the latter exhibit a less favourable assessment than the former.

From the observations here we cannot deduce a minor role of informal interaction as compared with formal interaction. Both for universities and for governmental research institutes we find the interaction propensity for formal interaction being of the same magnitude as that for informal interaction: 20% to 30%. The assessment of the informal interaction shows remarkably lower values than the formal collaboration. The rather low valuation of the informal interaction compared with the formal interaction suggests that most use can be derived from formal interaction. Knowledge and information exchange with universities and governmental research institutes is most efficiently conducted through formal channels. Our classification of informal interaction systematically underestimates the frequency of informal interaction as companies formally interacting with a partner can, at the same time, also interact informally. This cannot be covered with the available data.

Table 3-5. Informal interaction with knowledge-intensive services.

	Informal interaction with universities	Assessment of informal interaction with universities		Informal interaction with governm. research institutes	Assessment of informal interaction with gov. res. inst.	
All companies						
Services	0.270	0.169		0.237	0.109	
Manufacturing	0.312	0.203		0.306	0.208	*
Other Manufacturing	0.345	0.198		0.295	0.276	
Traditional Sectors	0.295	0.206		0.311	0.176	
Other Traditional Sectors	0.285	0.252		0.307	0.189	
Forest Cluster	0.334	0.052	***	0.328	0.129	

Note: Traditional sectors consist of the low-technology manufacturing and the low-medium-technology manufacturing. The forest cluster is represented by firms from the NACE classes 20, 21 and 361. The numbers give the fraction of companies with the respective characteristic extrapolated to all innovative Finnish companies. *** (**, *) indicates a significance level of 1% (5%, 10%).

3.1.4 Innovation-level analysis

In this section we shift the level of analysis from the firm to individual innovation projects. We leave the subject approach and here focus on the object approach.

3.1.4.1 Data

The data source used for this analysis is the database of Finnish innovations (Sfinno) established and maintained by the Technical Research Centre of Finland (VTT). In contrast to the CIS data used above, the Sfinno database contains information on innovations marketed in Finland from 1985 to 1997. We use data on some 802 innovations for which detailed survey data on the nature of the innovation and the process of its generation is available. The concept of the object approach implies that only successful innovations are recorded. This results in a data source where information on unsuccessful innovation projects is excluded by definition.

The detailed information on the innovation and its coming about is gathered by surveying the innovating firm. As in the CIS companies, the project managers of the innovation projects are asked about the collaboration and their assessment of its relevance in the development of the particular innovation. A detailed description of the information contained in the Sfinno database and its generation is in Palmberg et al. (1999) and Palmberg et al. (2000).

3.1.4.1.1 Results

Within this section we are interested in analysing the importance of knowledge-intensive services for the development of innovation. We utilise the innovating companies' project or innovation-based assessment of the relevance of the collaboration with universities, research institutes and consulting companies, and only focus on the companies' high esteem of the collaboration. Table 3-6 gives the fraction of innovation projects in which collaboration with the given type of partners was regarded as highly important.

Table 3-6. Relevance of collaboration partners for innovation.

	Universities	Research inst.		Consulting comp.	
All companies					
Other Manufacturing	0.627	0.550		0.544	
Traditional Sector	0.606	0.652	***	0.391	**
Other Traditional Sectors	0.690	0.702		0.467	
Forest Cluster	0.565	0.624		0.351	

Note: Cells contain the fraction of innovations generated in co-operative projects where the partner was assessed as highly important. Sector classification according to sector of the innovating company. Traditional sectors consist of the low-technology manufacturing and the low-medium-technology manufacturing. The forest cluster indicates innovations originating from or being diffused to firms from the NACE classes 20, 21 and 361. The numbers give the fraction of innovation with the respective characteristic. *** (**, *) indicates a significance level of 1% (5%, 10%).

We observe that the valuation of universities does not differ significantly between the whole sample of innovations and innovations introduced by companies from the traditional sectors. Also, the assessment of the importance of collaboration with universities does not differ between the sample of innovations from other traditional sectors and the sub-sample of innovations related to the forest cluster.

We find a significantly higher valuation of research institute collaboration for innovations in traditional sectors than for innovations in the high and medium-high-technology manufacturing sectors. At the same time we do not observe a difference in the valuation between innovation projects in the forest cluster and innovation projects in other traditional sectors. This pattern resembles the pattern of valuation of private research labs in the firm-level analysis. Also, we see no different valuation in the forest cluster than in the average traditional sectors

These observations are largely in line with the findings for universities and research institutes on the firm level. Yet the results for the consulting companies require some further consideration. The firm-level data suggests a high importance of collaboration with consulting services for the innovation activities. The project-level data suggests comparatively lower importance in the traditional sectors. It also suggests a strong difference in the valuation between the high-technology sectors and the traditional sectors. Within the traditional sectors we find no difference in the valuation. The question in the project-related Sfinno survey relates to the development of the innovation. Hence it clearly focuses on the technological development phase of the innovation. The question in the firm-level database relates to the innovation activities in general, which do not just include the technological development phase as covered by the project-level data; they also include commercialisation, marketing and management in general. The slightly different focus and the differences in the results lead us to deduce a low relevance of consulting services in the technological development of an innovation in the forest cluster. We also suggest the importance of consulting services in commercialisation and marketing of innovations and most probably in management.

3.1.5 Conclusion

This research investigated the role and the importance of knowledge-intensive service activities in the traditional sectors. Knowledge-intensive service activities are defined as innovation-related service activities delivered from inside or from outside the innovating company. As such, we investigated the interaction between the innovating company and various partners supplying knowledge-intensive services to the innovating firm, such as universities, research institutes, private research facilities (R&D labs, e.g.) and consulting companies. We used both firm-level data as well as innovation-level data.

Summarising the findings we can state that, first, there are some differences in the pattern of formal collaboration between services and manufacturing firms, as well as between high-technology manufacturing firms and the traditional sectors. Concentrating on innovating companies eliminates some of the differences.

Second, although there are differences in the pattern of formal collaboration there seems to be almost no significant differences in the assessment of the importance of the collaboration partners. Some results stand out though. Companies in the forest cluster maintain a valuation of the partners that differs from the assessment of the average other company in the traditional sectors.

Third, the analysis of the patterns and valuation of informal collaboration does not reveal any striking differences across the sectors and across types of partners.

Fourth, public funding induces companies to collaborate with a larger number of types of collaboration partners delivering knowledge-intensive services. It also succeeds in inducing companies to collaborate more intensely.

Fifth, the project-level or innovation-level data by and large confirms the observations from the firm-level data. However, it also suggests that consulting companies are more likely to be involved in the non-technical developmental phases of the innovation process.

Finally, based on the analysis we can suggest a ranking of the average importance of formal interaction with the four partners for the traditional manufacturing sectors:

First	Governmental research institutes
Second	Private research facilities
Third	Consulting companies
Fourth	Universities.

A caveat has to be issued here. As the whole analysis is based on observation of the average, and it is based on survey data, we may have averaged away certain aspects that could be relevant for understanding the role of knowledge-intensive service activities in the innovation activities of traditional manufacturing sectors. In this regard, case studies may shed more detailed light on the particular role knowledge-intensive services play in the traditional industries.

3.2 Determinants of R&D collaboration

3.2.1 Introduction

The analysis of firm collaboration can be motivated by four broad research questions that form a chronology of decisions and actions in firm co-operation.

The first research question focuses on the firm's motivation to co-operate. The second domain of the research concerns the selection of the collaboration partner. While engaging in the collaboration, firms have to control the co-operation and to settle conflicts arising from different interests. This is what the third research question focuses on. The last research targets the question about assessing the results of the co-operation (cf. e.g. Das & Teng 2000, Bayona, Garcia-Marco & Huerta 2001).

The analysis here is only concerned with the first and second research question. It focuses on the motives and the partners chosen for R&D collaboration. As firms are assumed to be guided by their own interests they are motivated to enter collaborative arrangements only if it is beneficial for them. Hence a discussion about the benefits of collaboration will give us an opportunity to deduce the underlying motives. Looking at the risks involved in collaboration enables us to analyse the reasons why companies do not collaborate. The benefits and risks of collaboration in general can briefly be summarised (Mowery 1998):

1. Collaboration enables companies to capture knowledge spillovers.

2. Co-operation reduces the duplication of research.

3. Collaboration makes it possible for companies to exploit economies of scale in R&D.

4. Co-operation accelerates the commercialisation of new technologies.

5. Collaboration facilitates the transfer of knowledge from universities and research institutes to industry.

6. Collaboration allows companies to get a glimpse of future technological development.

In what follows we analyse Finnish companies' motives for collaboration. We base our investigation on three cross-sectional innovation surveys. Comparing the results for the three time periods, we also try to shed some light on the changing pattern of collaboration that occurred from 1989 to 2000. As the data used in this study can be compared across Europe, we try to exploit this comparability in a later stage of the research – that is, it will not be documented here. Hence for comparability reasons we base both the data selection and the econometric set up of Tether (2002), who analysed the collaboration of companies in the United Kingdom.

The following sections then elaborate on the reasons why firms decide to collaborate for innovation. We will do so in a brief way, not elaborating fully on any possible benefit. But, by implicitly referencing the available data, the motives that can be analysed with the data at hand are discussed. The structure will be as follows. Section 3.2.2 will discuss a hypothesis on co-operative arrangements. In Section 3.2.3 we will introduce the data source and discuss the variables that are available for the analysis. The hypotheses will be tested in Section 3.2.4. Section 3.2.5 concludes and sketches extensions of the research conducted here.

3.2.2 Why do firms collaborate? – Some hypotheses

Assuming that firms commit to activities to increase their individual welfare rather than to increase the societal welfare, we predominantly focus this discussion on the advantageous effects of collaboration for the individual firm. The discussion of the benefits of collaboration can be structured according to the collaboration partner. The first set of partners belongs to the supply chain of the collaborating firm, and comprises suppliers and customers. The second group engages in horizontal collaboration, referring to collaboration with competitors. This study only considers the first category of collaboration partners as customers and suppliers are considered the most important collaboration partners for Finnish companies (Palmberg, Niininen, Toivanen & Wahlberg 2000).

3.2.2.1 General factors

The following sections discuss the factors that are deemed to determine collaboration in general, regardless of the choice of collaboration partner.

3.2.2.1.1 Size

Size matters for co-operative relationships. If one assumes that there is a given propensity to co-operate for a unit of economic activity, the larger the economic activity, the higher the probability to engage in collaborative arrangements (cf. e.g. Fritsch & Lukas 2001).

Hypothesis 1 *The probability of engaging in co-operative activities increases with the size of the company.*

On the one hand, Fritsch and Lukas (2001) and Bayona et al. (2001) find a positive and significant influence of the firm size on the firm's co-operation activities. In Kleinknecht and Reijnen (1992), however, no significant influence of the firm size on its general collaborative activities is found. For collaboration with research institutes, Kleinknecht and Reijnen (1992) reveal a positive and significant influence of the size variable. On the other hand, Veugelers (1997) reports a negative and significant sign of the size variable, indicating that smaller firms tend to have a higher probability of collaboration.

Tether (2002) analyses the collaboration propensity of firms for various types of collaboration partners. By and large, his analysis reveals a significantly positive sign of parameter estimate for the size variable. For collaboration with customers, however, the positive parameter estimate is not significant.

3.2.2.1.2 Absorptive capacities

It is also argued that collaboration is a complement to rather than a substitute for R&D due to the generation of absorptive capacities through in-house R&D (Cohen & Levinthal 1989, Cohen & Levinthal 1990, Pyka 1999). Extending this notion of complementarity and absorptive capacities, we see that companies cannot rely on a single source of knowledge; to be successful, companies have to engage in various activities related to acquiring knowledge. Collaboration will be one of them, and the more diversified the activities are the more beneficial each single activity will be to the company.

Hypothesis 2 *Companies with highly diversified activities in knowledge acquisition will show a higher frequency of collaboration.*

The analysis in Veuglers (1997) shows that firms spending more on R&D have a significantly higher probability of co-operating. Comparable results are presented in Fritsch and Lukas (2001), but Bayona et al. (2001) find no such relationship. Tether (2002) in his analysis of the 1996 U.K. innovation survey finds that R&D has a significant positive influence on the propensity to collaborate. The influence of high internal spending on R&D, however, is only significant for collaboration with suppliers and universities.

3.2.2.1.3 Experience

It can generally be assumed that positive experiences with collaborative arrangements in the past make the benefits of collaboration more obvious to the decision makers. Hence companies with positive experience of collaboration will have a higher propensity to collaborate in the future.

Hypothesis 3 *Companies that enjoyed a positive experience with collaborative arrangements have a higher propensity to collaborate.*

3.2.2.1.4 Disadvantages of collaboration

However, collaboration has certain disadvantages that are independent of the collaboration partner. The disadvantages arise merely in terms of transaction costs. Transaction costs occur due to the need for the collaboration partners to unify heterogeneous structures, due to the co-ordination of organisational routines, due to identifying and combining complementary assets, and due to costly pricing of the exchanged information or commodities. It may also be costly to establish rules that govern the appropriation of the innovation results. As the collaborators lack sufficient information about the partner and the technology, risks and uncertainties may still be relevant as they cannot be sufficiently dealt with by means of contracts (Besanko, Dranove & Shanley 2000).

Transaction costs in the form of risk associated with unknown partners mainly accrue due to a lack of information about the partner and the lack of mechanisms to increase the compliance of the collaboration partner.

If both collaboration partners are members of the same group, the information asymmetry may not be as severe as it would be otherwise; hence collaboration is more likely in this case.

Hypothesis 4 *Companies belonging to a larger group of companies are more likely to collaborate.*

3.2.2.2 Vertical co-operation

It is argued that collaboration within the supply chain can help to eliminate, or at least to reduce, the appropriability problem. Collaboration within the supply chain offers information guiding the firm's decision about the size of the funds spent on research and development and guides the decision maker where to allocate the funds (Shaw 1994). Across sectors, we can also observe different propensities to collaborate with customers or suppliers (von Hippel 1976, Clark et al. 1987).

Sometimes, vertical collaboration is more than just a short-term joint engagement. Often, it has the meaning of a long-term commitment and, as such, decisions for or against collaboration may be of a strategic nature. In this regard collaboration is also about joint and organisational learning and the establishment of trust (Besanko et al. 2000, Gill & Butler 1996).

3.2.2.2.1 Customers

Co-operation with customers can exploit knowledge complementarities. In particular, lead customers can provide knowledge of future demands. Involving customers in the development of an innovation can significantly reduce the development time as modifications to the design can be implemented more swiftly (Shaw 1994).

To make the innovation an economic success, appropriate pricing is essential for the acceptance of the novelty on the market. Close collaboration with customers helps to establish an appropriate pricing scheme.

Hypothesis 5 *Collaborations with customers are more likely to occur when firms experience a lack of knowledge about the future demand.*

New products, and new services in particular, require a learning process to extract the maximum utility possible from using or consuming the good or service (Gallouj & Weinstein 1997). The acceptance of the product in the market can also be facilitated by demonstrating the usefulness of the innovation with experimental customers that have been involved in the development process (Rothwell 1993). By means of collaboration firms try to reduce the economic risk involved in the marketing of innovations.

Hypothesis 6 *Co-operation with customers is more frequent when companies report that they are affected by economic risks involved in the innovation development.*

As, for example, Rothwell (1994) indicates, the innovation process can be characterised by an increasing complexity. It is argued that integration of customers helps the innovator to improve on his ability to deal with the complexity of the innovation that is being found in sectors with a high technological intensity (Dodgson 1994)[xiv]

Hypothesis 7 *Co-operation with customers is more frequent in sectors with a higher technological intensity.*

It can be argued that innovation-specific investments increase the risk associated with the development and marketing of innovations. This increased risk can be managed by engaging in collaboration with customers (Tether 2002).

Hypothesis 8 *Companies that invest in new machinery related to the development of innovations are more likely to collaborate with customers.*

The underlying idea in the discussion above is that the customers are being involved in the development process as they are the users or consumers of the novelty. If, however, the novelty only consists of a process innovation to be exploited by the innovating firm itself, 'innovation' refers to the increased efficiency in producing an old' commodity. Hence there is no need for customer involvement.

Hypothesis 9 *Co-operation with customers is less likely if the company reports a process innovation that is not accompanied by a product innovation.*

3.2.2.2.2 Suppliers

The discussion on collaboration with suppliers in the development of innovations intensified in the 1980s as the success of Japanese car manufacturers was attributed to the close customer and supplier relationship (Clark et al. 1987). Collaboration with suppliers can have a cost-saving effect when the firm's desire to outsource certain activities is intended to downsize the range of its own activities. Collaboration in this context can be seen as a substitute for a firm's own R&D. If this is the case, lower in-house R&D will go hand in hand with a higher collaboration probability.

Hypothesis 10 *Companies with a low in-house R&D will show a higher frequency of collaboration with suppliers.*

Reducing the financial burden of the innovation project by means of collaboration with suppliers only makes sense if the R&D efforts by the firm and the R&D carried out by the supplier are substitutes. If cost-sharing is a dominant motive for getting suppliers involved in the innovation project, we would also see an economic bottleneck experienced by the companies to increase the probability of collaboration with suppliers.

Hypothesis 11 *Increasing economic constraints result in an increasing probability to co-operate with suppliers.*

However, this contradicts the notion of absorptive capacities that we already formulated in hypothesis 2.

As mentioned above, collaboration is a strategy for managing technological complexity by accessing the complementary knowledge of the collaboration partner. This line of argument not only applies to collaboration with customers. It can be argued that collaboration with suppliers is also a means of managing the complexity of innovation.

Hypothesis 12 *Co-operation with suppliers is more frequent in sectors with a higher technological intensity.*

In this case the collaboration is about knowledge-sharing between collaboration partners. This knowledge-sharing is more important and more valuable to companies that experience a scarcity of knowledge.

Hypothesis 13 *Companies that experience a scarcity of knowledge are more likely to engage in co-operative arrangements with suppliers.*

The introduction of product innovations more often than not requires the reconfiguration of the production process. New or significantly changed production processes may cause new or modified demand for such input factors as materials, components or semi-fabricated products.

Hypothesis 14 *Co-operation with suppliers is more frequent if firms change their production process due to a product innovation.*

As discussed above, high spending on outside technology points to the acquisition of specialised or custom tailored technology. Collaboration with the supplier of this technology is an effective way to communicate the demanded specification.

Hypothesis 15 *Firms with high spending on outside R&D have a higher probability to co-operate with suppliers.*

3.2.2.3 Horizontal co-operation

Horizontal collaboration comprises partners that are at the same level of the production chain. Co-operation with competitors falls into this category. Collaborating competitors can overcome financial R&D constraints. Projects that are too large for one of the partners individually can jointly be carried out. Economies of scale and scope can be increased by horizontal co-operation.

Hypothesis 16 *Companies experiencing a high degree of economic risk are more likely to engage in R&D co-operation with competitors.*

Co-operation with competitors can help to internalise technological spillovers. Involving competitors in the development process can soothe the appropriability problem and thereby increase the incentives to innovate, and increase the internal R&D expenditure accordingly (D'Aspremont & Jaquemin 1988). The internalising of the knowledge spillovers can only be achieved by building up a sufficient amount of absorptive capacities. High in-house R&D spending is a precondition for collaboration in this regard. The hypothesis is also of special relevance in this regard. Miyagiva and Ohno (2002) show that collaboration is more likely when spillovers are high and innovations are incremental.

Hypothesis 17 *Collaboration with competitors is more likely if innovation is incremental.*

Apart from that, competitors might collaborate to yield synergies by each firm concentrating on its own core capabilities, to reduce investment risk and to foster mutual learning. Co-operation with competitors may enable companies to access the knowledge they lack.

Hypothesis 18 *Collaboration with competitors is more likely for companies that face constraints relating to their knowledge base.*

From the social perspective, collaboration with competitors can lead to a reduction in inefficient duplication of R&D efforts. The disadvantages of close research and development co-operation between competitors is the potentially increasing collusive behaviour, the incentive for inefficient R&D spending on the firm level, and the potentially reduced price competition in the commercialisation stage. On the firm level the transaction costs sketched above may represent a reason for not co-operating.

It can also be argued that although the collaborating companies are competitors they may not compete on the targeted market. This line of reasoning especially holds if horizontal collaboration arrangements are used to improve the competitive position on international markets (Chetty & Wilson 2003). In this regard, the probability of collaboration depends on the international orientation of the firm.

Hypothesis 19 *Companies with a strong international focus have a higher probability of collaborating with competitors.*

3.2.2.4 Universities and governmental research institutes

Governmental research laboratories as well as universities can be seen as the source of new scientific and technological knowledge and can assist companies with specific technological problems (Rappert, Webster & Charles 1999).

Hypothesis 20 *Firms experiencing a bottleneck in their knowledge endowment are more likely to collaborate with universities and governmental research institutes.*

This is even more relevant as collaboration with universities may enable firms to not only access knowledge but also highly qualified personnel (Hagedoorn, Link & Vonortas 2000, Jacobsson 2001).

It can be argued that the acquisition of knowledge and personnel is more relevant for companies in knowledge-intensive sectors.

Hypothesis 21 *The probability of a companies collaborating with universities increases with the knowledge-intensity of the company's sector of activity.*

The role of governmental research institutes has always been to engage in applied problem-solving rather than in basic research. Universities are developing in the same direction more and more. They are shifting from the academic generation of purely scientific knowledge to applied problem-solving (Schienstock & Hämäläinen 2001).

With appropriate financing support, university collaboration and co-operation with research institutes is regarded by firms as inexpensive and low risk, even more so as governmental technology financing is increasingly coupled with the requirement of collaboration.[xv] Hence they are attractive collaboration partners, although the universities and governmental research institutes are often considered as rather inflexible and slow.

Hypothesis 22 *Collaboration with universities and governmental research institutions is more likely for companies that face serious economic constraints.*

3.2.2.5 Consulting companies

Consulting companies and private research institutes can also play a role in supplying new technological and scientific knowledge. It is often assumed that they can achieve this on a more flexible basis than governmental research institutes and universities.

Collaboration with consultants can also be driven by cost-saving motives. In this context it is certainly geared towards process innovations and organisational change within the firm.

The expertise of consulting companies may also be used by firms who cannot assess future demand by close collaboration with customers. Consulting companies can assist firms to gather knowledge about future demands and thus help to reduce the risk and uncertainty associated with the development projects.

Hypothesis 23 *Collaborations with consulting companies are more likely to occur when firms experience a lack of knowledge about the future demand.*

Uncertainty about demand conditions may not only arise concerning the future; demand conditions on international markets cause considerable uncertainty. Consulting companies, particularly international consulting firms, can reduce this uncertainty and help companies to identify international market opportunities.

Hypothesis 24 *Collaborations with consulting companies are also more likely to occur if firms are targeting international markets.*

Consulting companies offer more than just technological or marketing expertise. They also offer managerial expertise. As collaboration can be seen as one way to manage the increasing complexity of the innovation process and the marketing of innovations, collaboration with consultancies should be more frequent where the technology is more complex.

Hypothesis 25 *Companies in more advanced sectors have a higher probability of co-operating with consultants.*

External expertise is particularly relevant in managing change within the company. First, the need for change management can occur due to organisational change within the company. Second, the realisation of product innovations may require changes in the production processes. Managerial expertise may be necessary for changing the production process efficiently. Third, integrating outside knowledge into the knowledge base of the company may be problematic due to a lack of absorptive capacities. The problems may be relaxed through the moderating effect of collaborating with consultants.

Hypothesis 26 *Firms experiencing organisational change exhibit a higher probability of co-operating with consultants.*

Hypothesis 27 *Companies changing the production process due to product innovations are more likely to collaborate with consulting companies.*

They may also function as a forum to share experience, and as a means of cross-fertilisation between firms.

3.2.3 Data

This section will introduce the data source that the following analysis is based on.

3.2.3.1 Data sources

Community innovation surveys CIS

The analysis of the collaborative arrangements of Finnish companies uses the three waves of the Community Innovation Survey (CIS-1, CIS-2, CIS-3) carried out by Statistics Finland in 1992, 1997 and 2001. The surveys cover the three preceding years and are abbreviated here by the last year of their coverage – i.e.

1991, 1996 and 2000. The surveys are conducted in a cross-section manner, such that the panel properties of the combined survey are almost negligible.

The first wave of the Community Innovation Survey was started jointly by Eurostat and the Innovation and SME Programme in 1991. The surveys collect firm-level data about innovation inputs, innovation outputs and general characteristics of the firms. The approach taken has certain advantages:

- Regular intervals of data collection.
- Representativeness of the data.[xvi]
- Data is comparable on the European scale.

The approach of the Community Innovation Survey, however, carries also a number of shortcomings.

- Slightly changing conceptual background.
- The innovation surveys are harmonised across European countries but the surveys are not harmonised over time. Different surveys contain different questions, or ask questions in different ways.
- The survey does not intend to have extensive panel properties.
- The surveys are not pre-tested to make sure that companies really comprehend the questions posed in the questionnaire.
- This is even worse as the survey is a mail survey, which causes a high threshold for companies to clarify the questions.
- For certain research questions the data is shown not to be sufficient. E.g. only innovators are asked to reveal their R&D efforts.

Despite their shortcomings, the innovation surveys represent a unique data basis.

Data base of Finnish Innovations

The database of Finnish innovations (Sfinno) contains information on 1,526 innovations developed and commercialised mainly between 1985 and 1998. The data set is documented in Palmberg, Leppälahti, Lemola and Toivanen (1999) and Palmberg et al. (2000). Although Sfinno follows the object approach, the information can be linked to the firm-level data by the information about the commercialising firm.

Business register

The business register of Statistics Finland is used in this analysis to fill gaps in the CIS data and the Sfinno database.

3.2.3.2 Definitions and variables

The variables that are going to be relevant for the analysis below will be defined in this section. The data available in the innovation surveys contains data about company characteristics, innovation output, innovation input, sector of companies' activity, and the factors hampering innovation activity. Where variables are not comparable across time we also discuss how we can proceed to make the data at least comparable on a somewhat more abstract level.

3.2.3.2.1 Output of the innovative activities

The data on the results of the innovative activities contained in the innovation surveys and the Sfinno database enables us, at least partially, to deduce the aims of the innovative activities. We distinguish the companies according to their reported innovation results (Table 3-7).

Table 3-7. Innovation output variables.

Variables	
inpd	Indicates product innovators, i.e. companies that reported having introduced a product innovation.
inpc	Points to the companies having reported the introduction of a process innovation.
inn	Indicates an innovator, either product innovator or process innovator.
inpoc	Indicates companies that realised process innovations only.
sfinno	Indicates an innovation in the Sfinno database in the years covered by the CIS. This variable tries to capture the novelty indicator used in several other studies, e.g. in Tether 2001. We have to use this variable as the 1991 CIS survey does not contain a question related to the market novelty of the innovation.

3.2.3.2.2 Sector of companies' activities

The sector of the companies' activities is coded according to the classification suggested by Hatzichronoglou (1997) and OECD (2001), giving a classification about the technology-intensity of the companies. This classification is based on the firms' industrial classification and assigns the companies by technology intensity as follows (Table 3-8). [xvii]

Table 3-8. Sectoral variables

Variable	
ltm	The low-technology manufacturing firms are taken from the following sectors: food and beverages (15, 16), textiles and clothing (17, 18, 19), wood and furniture (20, 361), pulp and paper (21), publishing and printing (22), and recycling (37).
lmtm	Low-medium-technology manufacturing companies are from shipbuilding (351), petroleum refining (23), other transport equipment (354, 355), rubber and plastic equipment (25), non-metallic mineral products (26), basic metals (27) other manufacturing (36 excluding 361) sectors.
hmtm	Represents the high-medium-technology manufacturing, which are the firms whose activity is in the following sectors: scientific instruments (33), electrical machinery (2971, 31, 323), motor vehicles (34, 352), motor vehicles (34, 352), chemicals (24 excluding 244), non-electrical machinery (29 excluding 2971)
htm	High-technology manufacturing comprises the following sectors: Aerospace (353), computers (30), electronics and telecommunication equipment (321, 322), biotechnology (244).
kis	Indicates sectors belonging to the high-technology services: post and telecommunication (64), finance and insurances (65, 66, 67) and business activities (71, 72, 73, 74).
os	Indicates all the other services.

3.2.3.2.3 Input to the innovation activities

The innovation survey supplies information about the companies' allocation of R&D expenditure to various categories. This allows us to derive an entropy index of the diversification of R&D effort and to establish various indicators of the R&D activities of the company. The information in the Sfinno database is utilised to derive the innovation experience of the company (Table 3-9).

Table 3-9. Innovation input variables.

Variable	
Rd	Indicates R&D effort of the company.
Rddiv	Diversification index of the R&D effort based on the information about R&D effort in the innovation survey.
Sfbf	Indicates the innovation experience of the company. It is 1 if the company has introduced an innovation identified by the Sfinno database in the years of the innovation survey and before.
Mac	Machinery is acquired for innovation activities.

3.2.3.2.4 Experienced hampering factors

The discussion below will make clear that collaboration is a strategy to manage bottlenecks in the innovation process. A thorough analysis of the collaboration behaviour and interpretations concerning the underlying motives is not possible without information about the factors that are perceived as being the bottlenecks.

The innovation surveys contain information about which factors the companies regarded as hampering their innovative activity. The questions, however, are not posed in a homogenous manner in the years.

Firms' hampering factors in the surveys 1991, 1996 and 2000

The data taken from the innovation surveys is not directly comparable because the recorded categories, as well as the scale of the possible answers, are not consistent over the years. Hence at this level of detail the answers are not comparable at all. The question that arises here is whether, due to this inconsistency of the available data, we can proceed in the direction of comparing the three surveys or whether we can at least try to get an impression of the overall changes in the hampering factor.

Background factors

Abstracting from the available details we might find certain 'meta-factors' that are the basis of the detailed answers recorded in the individual surveys. These 'meta-factors' can be derived if we look at the systemic approach to innovation, and the decisions within the firm that are to be considered in this regard:

1. economic aspects of the innovation project

2. technological, knowledge or capability aspects of the innovation project

3. aspects of co-operation with institutions that are regarded as knowledge sources

4. fitting the innovation project into the corporate strategy, i.e. long-term considerations.

These considerations – deducing the background factors or 'meta-factors' from the data of the surveys – enable us to compare the hampering factors over time. A common methodology for extracting unobserved background factors from observed variables is principal component analysis.[xviii]

Procedure and results

Principal component analysis is employed on each of the three available innovation surveys. The results of the principal component analysis clearly show that there are consistent underlying factors in all three innovation surveys: economic hampering factors and technological (or internal) hampering factors. The factor scores for each year have a zero mean and a unit variance (Table 3-10).

Table 3-10. Hampering factors.

Variable	
hampeco	Gives the intensity of the hampering factors related to economic factors, such as too high a risk, and to less financial resources and the like.
hampkno	Indicates the intensity of the experienced bottleneck of the companies relating to knowledge, such as too little knowledge about the market, too little technical knowledge, too few qualified personnel, and resistance within the company.

3.2.4 Multivariate Analysis

The multivariate analysis focuses on the hypotheses developed above. The hypotheses, the variables and the expected signs of the parameter estimate are summarised in Table 3-11 and 3-12.

The analysis of the hypotheses is carried out for a restricted sample containing only the companies identified above as innovators (inn=1). The general procedure employed here is to estimate a 'full' model containing all exogenous variables and then delete variables that do not show a significant parameter estimate and do not contribute to the overall fit of the model.[xix]

Table 3-11. Summary of the hypotheses I.

Hypothesis	Keyword	Variable	exp. Sign
Customers			
1	Size	empl	+
2	Absorptive capacities	rddiv	+
3	Positive experience	sfbf	+
4	Member of group	conc	+
5	Knowledge bottleneck	hampkno	+
6	Economic bottleneck	hampeco	+
7	High-tech. sector	htm/hmtm	+
8	Special investment	mac	+
9	Only proc. innov.	inopc	-
Suppliers			
1	Size	empl	+
2	Absorptive capacities	rddiv	+
3	Positive experience	sfbf	+
4	Member of group	conc	+
	Substitution	rddiv/rd	-
	Economic bottleneck	hampeco	+
	High-tech. sector	htm/hmtm	+
	Knowledge bottleneck	hampkno	+
	Process innovation	inopc/mac	+
Competitors			
1	Size	empl	+
2	Absorptive capacities	rddiv	+
3	Positive experience	sfbf	+
4	Member of group	conc	+
	Economic risk	hampeco	+
	Incremental innovation	sfinno	-
	Knowledge bottleneck	hampkno	+
	International focus	exsh	+

Table 3-12. Summary of the hypotheses II.

	Keyword	Variable	exp. Sign
Universities and research institutes			
1	Size	empl	+
2	Absorptive capacities	rddiv	+
3	Positive experience	sfbf	+
20	Knowledge bottleneck	hampkno	+
21	High-tech. sectors	htm/hmtm	+
22	Economic constraints	hampeco	+
Consultants			
1	Size	empl	+
2	Absorptive capacities	rddiv	+
3	Positive experience	sfbf	+
23	Knowledge bottleneck	hampkno	+
24	International focus	exsh	+
25	High-tech. sector	htm/hmtm	+
26	Organizational change	orch	+
27	Restructuring processes	mac	+

3.2.4.1 Collaboration with customers

Table 3-13 displays the results of the regression of the customer collaboration on the above discussed exogenous variables. Column 'full' gives the parameter estimation for the full model and 'red.' reports the results for the reduced model. The marginal effects computed for the mean of the exogenous variables is computed only for the reduced model and reported in Table 3-14.

Table 3-13. Collaboration with customers.

	1991				1996				2000			
variable	full		red.		full		red.		full		red	
(Intercept)	–3.4390	***	–3.3389	***	–2.3583	***	–2.0128	***	–2.2051	***	–2.6732	***
a.inopc	–0.1147		x		–0.6647	*	–0.7234	*	–0.3994		x	
a.mac	–0.1329		x		0.2924		0.3799	*	0.3386	*	0.2966	.
a.sfbf	0.1069		x		0.2973		x		0.6550	**	0.6381	**
a.sfinno	–0.1057		x		–0.2359		x		–0.4826		x	
b.conc	0.3887	.	0.4486	*	0.6534	**	0.7834	***	0.3528	.	0.3688	*
b.empl	0.2460	**	0.2141	**	0.0470		x		0.3016	***	0.2989	***
b.exsh	–0.2142		x		0.5067	.	0.6124	*	0.3197		x	
b.lprod	–0.8954		x		1.2774	*	1.3159	*	0.0160		x	
b.orch	0.6221	**	0.6572	***	0.1274		x		–0.0539		x	
c.hmtm	0.7626	**	0.6619	**	0.4775	.	0.3317		0.669	**	0.753	***
c.htm	0.7224		0.6659		0.5291		x		0.6844		0.7336	10.7%
c.kis	0.6746		x		0.6438	*	0.5677	*	0.8578	***	0.8653	***
c.lmtm	0.6642	*	0.521	*	0.6021	*	0.4595	.	0.4685	.	0.52	*
c.os	0.2670		x		–0.7591	*	–0.9015	**	0.0201		x	
d.rd	0.1505		x		0.8844	.	0.9234	.	–0.5251		x	
d.rddiv	1.0034	***	1.0175	***	0.2562		x		0.6869	***	0.6732	***
e.hampeco	0.0331		x		–0.0372		x		0.1396	*	0.1390	*
e.hampkno	0.1461		0.1699	10.4%	0.2595	***	0.2674	***	0.1354	.	0.1361	*
N	582		582		665		665		832		832	
pseudo-R^2	0.188		0.178		0.245		0.235		0.237		0.229	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 3-14. Marginal effects – collaboration with customers.

variable	1991	1996	2000
innovation activity – output			
a.inopc		–17.83	
a.mac		9.44	7.37
a.sfbf			15.78
a.sfinno			
characteristics			
b.conc	9.10	19.24	9.15
b.empl	4.46		7.45
b.exsh		15.21	
b.lprod		32.69	
b.orch	13.80		
sectoral classification			
c.hmtm	14.58		18.58
c.htm			17.91
c.kis		13.68	21.16
c.lmtm	11.38	11.16	12.92
c.os		–21.96	
innovation activity – input			
d.rd		22.33	
d.rddiv	21.17		16.78
hampering factors			
e.hampeco			3.47
e.hampkno	3.53	6.68	3.39

Innovation survey 1991

The most significant influences in the analysis of the innovations survey in 1991 are the organisational change (orch) and the index for diversification of R&D efforts. Both parameter estimates are positive. The low-medium (lmtm) and the high-medium (hmtm) technology manufacturing sectors show significantly more frequent collaboration with the customers than the low-technology manufacturing sector, which is the basic category in our analysis. In sharp contrast to this, the high-technology manufacturing sector (htm) does not reveal a collaboration frequency that is significantly different from that in low-technology manufacturing. We find an inverted u-shaped relationship between the technological intensity of the sectors in which firms operate and the propensity to collaborate with customers. The severity of the experienced bottleneck in the knowledge domain also contributes positively to the probability of collaboration.

Innovation survey 1996

An inverted u-shaped relationship between the technological intensity of the sector and the firms' propensity to collaborate is also found in 1996. In 1996 the fact that companies exerted R&D efforts (rd) at all increases their probability to collaborate with customers. The diversity of these efforts (rddiv), however, has no significant influence. In the variable group describing the firm characteristics the group dummy (conc), the export orientation (exsh) and the labour productivity (lprod) are significantly different from zero. The technology intensity of the sectors of companies' activities shows an inverted u-shaped influence on the probability to innovate. Firms in the low-medium-technology manufacturing sector show an 11% higher probability to be innovators than companies from the low-technology manufacturing. Along the increasing technological intensity the distance to the low-technology manufacturing decreases considerably: 0% for the high-medium-technology manufacturing and 0% for the high-technology manufacturing. Companies in the knowledge-intensive service sector, however, show a 13% higher probability in collaboration with customers. The other services exhibit a reduced probability of collaboration with customers compared with the low-technology manufacturing. It also showed that companies that only produced a process innovation engaged considerably less frequently in collaborative arrangements with customers. Innovation-related investment in machinery also increases the propensity to collaborate. Experienced bottlenecks in the knowledge domain contributed positively to the probability of collaboration with customers.

Innovation survey 2000

By and large, the probability to collaborate with customers increases with the technological intensity of the sector of the firm' activities. Yet, a slight u-shaped relationship remains as the marginal effect of the high-medium-technology manufacturing (hmtm) is slightly higher than the marginal effect of the high-technology manufacturing sector (htm), which is slightly insignificant at the 10% level. Comparable to 1991, a positive and significant parameter estimate of the size variable (empl) and the group membership variable (conc) can be found here. Investment in machinery related to innovation projects contributes positively to the probability of collaboration with customers. The diversification index of R&D activities also shows a significantly positive parameter estimate. And the positive influence of the innovation history (sfbf) increases the firm's propensity to collaborate. Both the severity of the experienced economic and the knowledge bottleneck obtain a positive parameter estimate.

Comparison

The factors determining the collaborative activities with customers show a very heterogeneous composition over the years. Companies that only improved their processes without marketing a product innovation show no difference in their propensity to collaborate with customers compared with companies that also marketed a product innovation in 1991. In the 1996 survey only process innovators are more unlikely to engage in collaboration with customers, not so in the 2000 survey though. In 1991 the membership of a larger group of companies does not matter for the co-operation with customers. Yet it strongly influences the propensity to collaborate with customers in 1996. In the 2000 survey we also obtain a positive parameter estimate. For all three innovation surveys we find that companies that belong to a larger group of companies exhibit a higher probability to collaborate. Concerning the sectors of the companies' activities, we find that the service sector in general experienced an increase in its propensity to collaborate from 1996 to 2000.[xx] In no survey do the high-technology manufacturing companies seem to collaborate more frequently with customers than the low-technology manufacturers. As either only the low-medium-technology manufacturing sector or the low-medium and the high-medium-technology manufacturing sector co-operate more frequently with customers, we obtain an inverted u-shape relationship between technological intensity and the probability to collaborate. The interesting result in the Finnish case here is that the high-technology-manufacturing sector showed no significantly larger propensity to collaborate than the low-technology manufacturing – a result that contradicts findings from various other studies with comparable data sets. For example, Tether (2002) for U.K. data and Bayona et al. (2001) for Spanish data show that collaboration with customers is more likely to occur in high-technology sectors. The result obtained here for the Finnish companies, however, may be explained by the different structure of the Finnish economy in high-technology manufacturing.[xxi] The story about absorptive capacities can be told for the years 1991 and 2000. In the 1996 survey the indicator of R&D activity obtains a positive significant parameter estimate. It is tempting to interpret this in favour of the absorptive capacities hypothesis. The influence of the hampering factor associated with knowledge shortages is relevant for collaboration for all investigated innovation surveys. In 1996, however, it has a remarkably larger marginal effect. This shows that knowledge is a scarce factor that can be obtained by collaboration. As the collaboration here only concerns collaboration with customers, the most probable shortage in this category relates to the uncertain characteristics of the demand. The influence of the economic hampering factors only appears by the end of the 1990s. This indicates that, at least according to the companies' perception, innovation became more risky by the end of the 1990, which was probably due to the dynamic development of the IT sector, which attracted most of the public attention and also most of the attention of potential financiers.

3.2.4.2 Collaboration with suppliers

In Table 3-15 and Table 3-16 we depict the results of the analysis for the co-operation with the suppliers, where Table 3-15 contains the parameter estimates for the full and the reduced models and Table 3-16 gives the marginal effects for the reduced models. The tables only contain results for the surveys of 1996 and 2000, as the 1991 innovation survey does not ask questions relating to the co-operative activities with suppliers.

Table 3-15. Collaboration with suppliers.

	1996				2000			
variable	full		red.		full		red	
(Intercept)	–2.8724	***	–3.0906	***	–2.0752	***	–2.4499	***
a.inopc	–0.2795		x		0.0577		x	
a.mac	0.5407	**	0.5614	**	0.3877	*	0.3269	*
a.sfbf	0.1059		x		0.5239	*	0.4680	*
a.sfinno	0.0622		x		–0.6361		x	
b.conc	0.3802	.	0.4171	*	0.1385		x	
b.empl	0.2139	***	0.2342	***	0.371	***	0.3757	***
b.exsh	–0.0399		x		0.0645		x	
b.lprod	0.8310	.	0.8534	*	1.2398	**	1.2565	**
b.orch	0.1677		x		–0.2328		x	
c.hmtm	–0.2179		x		0.0849		x	
c.htm	0.1378		x		–0.0415		x	
c.kis	–0.2853		x		0.1671		x	
c.lmtm	0.0828		x		–0.1926		x	
c.os	–1.2563	***	–1.1569	***	–0.37		–0.3613	
d.rd	1.014	.	1.0359	.	–0.4818		x	
d.rddiv	0.5653	**	0.556	**	0.8598	***	0.8116	***
e.hampeco	0.0369		x		0.1280	.	0.1258	.
e.hampkno	0.191	**	0.2158	***	0.1905	**	0.1868	**
N	665		665		832		832	
pseudo-R^2	0.206		0.198		0.204		0.194	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 3-16. Marginal effects – collaboration with suppliers.

variable	1996	2000
innovation activity – output		
a.inopc		
a.mac	13.93	8.15
a.sfbf		11.53
a.sfinno		
characteristics		
b.conc	10.39	
b.empl	5.85	9.38
b.exsh		
b.lprod	0.02	0.03
b.orch		
sectoral classification		
c.hmtm		
c.htm		
c.kis		
c.lmtm		
c.os	–26.94	
innovation activity – input		
d.rd	24.17	
d.rddiv	13.90	20.27
hampering factors		
e.hampeco		3.14
e.hampkno	5.38	4.67

Innovation survey 1996

The group membership (conc) as well as the size (empl) exerts a significantly positive influence on the probability of collaboration with suppliers. All manufacturing sectors and the knowledge-intensive services (kis) do not exhibit a propensity to collaborate with suppliers that is different from the propensity in the low-technology manufacturing. Only the other services sector co-operates significantly less. Both the indicator of the R&D effort (rd) and the index (rddiv) for the diversity of the R&D effort obtain a significantly positive parameter estimate. Companies that acquire new machinery in association with innovation projects collaborate more often with suppliers. The gravity of bottlenecks in the knowledge (hampkno) domain is also found to increase the probability to collaborate with suppliers.

Innovation survey 2000

Firm size (empl) and its productivity are the significant determinants of collaboration with suppliers among the firm characteristics. Across the different levels of technology intensity, companies do not differ significantly in their propensity to collaborate with suppliers. The probability of collaboration with suppliers increases with the acquisition of machinery and the firm's innovation history and its diversity of innovation activities. Both knowledge and economic bottlenecks (hampkno, hampeco) increase the probability of supplier collaboration, although the economic bottlenecks are slightly insignificant.

Comparison

Hypothesis 10 is based on the assumption that collaboration with suppliers is a substitute for R&D. On the grounds of the above analysis we have to reject this hypothesis for both 1996 and 2000 as the diversity of R&D efforts has a positive influence on the propensity to collaborate. In line with this rejection we also have to reject hypothesis 11, at least partially. Cost sharing may be a motive for collaboration with suppliers, but not a significant one though. Rather, collaboration is a lack of knowledge that drives companies to collaborate with suppliers; we find support for hypothesis 13. Neither do we find support for the hypothesis relating to the management of technological complexity, thus we reject hypothesis 12. Sectors that are assumed to be dealing with higher complexity do not collaborate more frequently.

We argued above that changing the production process due to the introduction of a product innovation has an influence on the firms' propensity to collaborate with suppliers. As this updating of the production process can be approximated with the variable about spending on the new machinery (mac), we find no support for the related hypothesis 14.

For the year 2000 we also find support for the hypothesis about the influence of past positive experience with collaboration on today's collaboration. The analysis here supports the view that collaboration with suppliers is about knowledge sharing rather than cost sharing. Collaboration with suppliers turns out to be highly dependent on the size of the company. The magnitude of the influence rises considerably from 1996 to 2000. The effect of the bottleneck in the knowledge domain decreased over time. However, the influence of the economic hampering factors seems to increase from 1996 to 2000, although they are not significant for 2000.

3.2.4.3 Collaboration with competitors

Table 3-17 and Table 3-18 display the regression results and the marginal effects of the analysis of collaboration with competitors.

Table 3-17. Collaboration with competitors.

	1991				1996				2000			
variable	full		red.		full		red.		full		red	
(Intercept)	–4.7285	***	–4.8927	***	–3.6604	***	–2.5555	***	–4.5263	***	–3.5512	***
a.inopc	–0.2983		x		–0.3273		x		0.2741		x	
a.mac	0.2272		x		0.8684	***	0.9219	***	0.3234		0.3645	.
a.sfbf	0.2802		x		0.255		x		0.4635	.	0.5236	*
a.sfinno	0.1062		x		0.6379	.	0.9953	***	0.5834		x	
b.conc	–0.7501	**	–0.7302	**	0.3058		0.4578	*	–0.0404		x	
b.empl	0.5355	***	0.5706	***	0.0586		x		0.2544	***	0.2656	***
b.exsh	–0.1502		x		–0.1439		x		0.4572	.	0.4242	
b.lprod	0.034		x		0.5437		0.6078		0.6242	.	0.7033	*
b.orch	0.1668		x		0.1111		x		–0.288		x	
c.hmtm	0.4139		0.4241	.	–0.79	**	–0.8085	***	–0.1304		x	
c.htm	0.8795	.	1.0803	*	0.1067		x		0.4762		x	
c.kis	–0.3002		x		0.1371		x		0.1882		x	
c.lmtm	0.3975		0.422	.	–0.1744		x		–0.1304		x	
c.os	0.0306		x		–0.6011		–0.5658		0.0893		x	
d.rd	0.7835		0.9234	.	1.0621		x		1.1234		x	
d.rddiv	0.7808	**	0.8163	**	0.4574	.	0.5408	*	0.5627	*	0.5767	*
e.hampeco	0.0978		x		0.0972		0.1312	.	0.1554	.	0.1987	**
e.hampkno	–0.1859		–0.1641		0.0437		x		0.0697		x	
N	582		582		665		665		832		832	
pseudo-R^2					0.206		0.198		0.204		0.194	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 3-18. Marginal effects – collaboration with competitors.

variable	1991	1996	2000
innovation activity – output			
a.inopc			
a.mac		13.56	5.19
a.sfbf			8.48
a.sfinno		18.92	
characteristics			
b.conc	–14.48	7.20	
b.empl	10.88		3.87
b.exsh			6.18
b.lprod		9.62	10.25
b.orch			
sectoral classification			
c.hmtm	8.49	–11.56	
c.htm	24.41		
c.kis			
c.lmtm	8.46		
c.os		–7.79	
innovation activity – input			
d.rd	14.59		
d.rddiv	15.57	8.56	8.41
hampering factors			
e.hampeco		2.02	2.89
e.hampkno	–3.14		

Innovation survey 1991

No variable about the innovation activity output obtains a significant estimate. Size is a significantly positive predictor of collaboration behaviour. Companies that are members of a group of companies collaborate significantly less with competitors. In the manufacturing sector the technological intensity has a positive influence on the propensity to collaborate with competitors. Both R&D effort and its diversity contribute positively to the probability of collaboration. Companies that experienced a knowledge bottleneck tend to engage in collaborative arrangements with competitors less frequently.

Innovation survey 1996

Both the novelty of the innovation (sfinno) and the acquisition of new machinery (mac) show significantly positive parameter estimates. On the input side of the innovation activities we find a positive parameter estimate for the index of diversification index (rddiv). Belonging to a larger group of companies (conc), as well as the labour productivity (lprod), receive a positive parameter estimate. The size variable (empl) has no influence in this analysis. The sector of firm's activity does not affect the probability to collaborate. Two exceptions here are the high-medium-technology manufacturing and the other services, which have a significantly negative influence on the probability to collaborate with competitors. The more severe the economic hampering factors, the more firms tend to collaborate with customers.

Innovation survey 2000

Companies' propensity to collaborate with competitors increases with the acquisition of machinery and the positive experience of collaboration. A number of variables related to the characteristics of the firm also have a positive influence on the collaboration – i.e. the size (empl), the export orientation (exsh) and the labour productivity (lprod). In this analysis the technological intensity does not influence the probability of collaboration. The scarcity of knowledge (hampkno) does not influence the collaboration behaviour. Moreover, it is the economic constraints (hampeco) that increase the probability to engage in collaborative arrangements with competitors.

Comparison

In the general hypotheses we assumed the company would increase the probability to collaborate (hypothesis 1). For co-operation involving competitors, we find support for this hypothesis for the years 1991 and 2000. The transactions costs of collaboration we argued are reduced if the company and the collaborator are from the same group of firms. The indicator for group membership (conc), however, shows no consistent influence over time. In 1991 it has a strongly negative influence, in 1996 it has a strongly positive influence and in 2000 it has no influence at all.

A positive influence of the past experiences with collaboration can only be found in 2000. The experience does not have any influence in 1991 and 1996. In all innovation surveys we find strong support for hypothesis arguing about absorptive capacities.

Experienced scarcity of knowledge is proposed in hypothesis to have a positive influence on the commencement of collaborative arrangements with competitors. However, we do not find any positive influence of the experienced knowledge scarcity; rather, we obtain a negative influence in 1991. Yet we detect indications of an increasing trend over the years. In hypothesis 16 we argued that economic constraints might increase the probability of collaboration with competitors. Although we do not find this positive influence in 1991, we detect a positive trend over the years eventually leading to significantly positive parameter estimates in 1996 and 2000. The hampering factors as a group of influences seem to increase in their importance as we find a positive trend for both the knowledge and the economic factors (hampkno, hampeco).

The argument behind hypothesis 17 is that collaboration with competitors is more likely if innovation is incremental. We do not find support for this hypothesis in either of the analyses, as we would expect a negative influence of the novelty variable (sfinno). Hypothesis 19 established a nexus between the companies' orientation towards international markets and its propensity to collaborate with competitors. Our analysis only supports this hypothesis in the year 2000.

3.2.4.4 Collaboration with universities

Table 3-19 and 3-20 show the results of the analysis for collaboration with universities and research institutes.

Table 3-19. Collaboration with universities and research institutes.

	1991				1996				2000			
variable	full		red.		full		red.		full		red	
(Intercept)	–8.0745	***	–7.5246	***	–3.3851	***	–3.3294	***	–4.5797	***	–4.1321	***
a.inopc	0.3792		x		–0.9693	**	–0.933	**	–0.0695		x	
a.mac	0.0479		x		0.0251		x		0.2315		x	
a.sfbf	0.4419		0.5966		0.4852		0.4727		0.957	***	0.8956	***
a.sfinno	0.2591		x		0.7292	.	0.8082	*	–0.6866		x	
b.conc	–0.057		x		0.7689	***	0.7710	***	0.3548	.	0.3387	.
b.empl	0.8933	***	0.8692	***	0.2921	***	0.2738	***	0.5594	***	0.547	***
b.exsh	0.3963		x		0.7608	*	0.8307	**	0.5479	*	0.5822	*
b.lprod	0.1106		x		0.4395		x		1.6127	***	1.5824	***
b.orch	0.4259	.	0.4385	*	–0.1753		x		–0.1984		x	
c.hmtm	0.6537	*	0.5744	*	0.3749		0.4069	.	0.507	*	0.4242	*
c.htm	2.0568	***	1.9212	***	0.4323		x		0.2063		x	
c.kis	–0.682		–0.8911		–0.2232		x		0.5844	*	0.4813	*
c.lmtm	0.2939		x		0.3938		0.4189		0.1763		x	
c.os	0.2336		x		–1.902	***	–1.8328	***	–0.5597		–0.6628	*
d.rd	1.6375	*	1.4456	*	1.0003		1.004	.	0.2730		x	
d.rddiv	1.1601	***	1.2254	***	0.5122	*	0.5386	*	1.3023	***	1.4017	***
e.hampeco	0.1657		x		0.1199		x		0.2500	***	0.2709	***
e.hampkno	–0.0048		x		0.1124		0.1624	*	0.0358		x	
N	582		582		665		665		832		832	
pseudo-R^2					0.206		0.198		0.204		0.194	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 3-20. Marg. effects – collaboration with universities and res.institutes.

variable	1991	1996	2000
innovation activity – output			
a.inopc		–22.41	
a.mac			
a.sfbf	13.34	11.66	21.88
a.sfinno		19.39	
characteristics			
b.conc		19.03	8.40
b.empl	18.08	6.84	13.62
b.exsh		20.75	14.50
b.lprod			39.40
b.orch	9.18		
sectoral classification			
c.hmtm	12.57	10.09	10.56
c.htm	44.65		
c.kis	–15.14		11.97
c.lmtm		10.33	
c.os		–39.23	–15.84
innovation activity – input			
d.rd	22.87	23.71	
d.rddiv	25.49	13.45	34.90
hampering factors			
e.hampeco			6.75
e.hampkno		4.06	

Innovation survey 1991

In the 1991 survey the collaboration experience exerts a significantly positive influence on the propensity to collaborate. The indicator of R&D effort (rd) and the index of R&D diversification (rddiv) also obtain a significantly positive parameter estimate. Size (empl) and organizational change (orch) have a positive influence on the companies' probability to collaborate with universities or research institutes. The propensity to collaborate also increases with the technological intensity in the sector of the companies' activities. No difference, however, can be found between the low-technology manufacturing sectors and the low-medium-technology manufacturing sectors.

Innovation survey 1996

Companies realizing process innovations that are not accompanied with product innovations have a significantly lower propensity to collaborate with universities and research institutes. The past experience of the company and the novelty of the innovations marketed by the company influence the propensity to collaborate positively. Companies belonging to a group of companies also have a higher tendency to collaborate with universities. Both the size of the company and its export orientation have a positive influence on the companies' propensity to collaborate. The technological intensity shows an inverted u-shaped relationship with, ceteris paribus, both the low and the high-medium-technology manufacturing sectors, having a 10% higher probability to collaborate with universities compared with both the high and the low-technology manufacturing sectors. The knowledge-intensive service sectors do not collaborate significantly more often with universities and research institutes than the low technology manufacturing sectors do. The other services, however have a 39% lower probability to collaborate with universities.

Innovation survey 2000

In the group of variables characterizing the firms' innovation output the only significant variable is the past experience of the collaboration (sfbf). The diversity of R&D efforts is also a significant determinant of the collaboration probability. Among the firm characteristics, all variables but the organizational change (orch) obtain a positive and significant parameter estimate. Companies belonging to a group of companies have an 8% higher probability to collaborate with universities than single companies. Both the size (empl) and the export orientation, as well as the labour productivity, of the company increase the firm's propensity to collaborate.

The technological intensity shows an inverted u-shaped influence on the collaboration, with the high-medium-technology manufacturing having an 11% higher probability to collaborate than all the other manufacturing sectors. The knowledge-intensive services have a collaboration probability comparable to the collaboration probability of the high-medium-technology manufacturing sector.

Comparison

In any of the three innovation surveys we find support for hypothesis 1, suggesting a positive influence of the size of the company on the collaboration probability. The hypothesis about the absorptive capacities is also supported by the analysis here, as the diversity of the R&D effort has a positive influence on the probability of collaboration with universities and research institutes. Companies with a positive past experience of collaboration tend to collaborate more frequently with universities and research institutes, giving support to hypothesis 3. The size of the effect remains quite stable from 1991 to 1996, and increases markedly from 1996 to 2000. The experienced bottlenecks do not exhibit a constant influence on the collaboration probability. In 1991 no influence can be detected. In 1996 it is the scarcity of knowledge increasing the likelihood of collaboration with universities and research institutes. Yet in 2000 it is the economic constraints giving rise to an increased probability of collaboration. Hence we find only partial support for hypothesis 20 and hypothesis 21.

The knowledge-intensity of the sectors the companies operate in has an increasing influence on the probability of collaboration only in 1991. Hence 1991 supports hypothesis 21. In 1996 and 2000 we find the inverted u-shaped influence lending no support to hypothesis 21.

3.2.4.5 Collaboration with consultants

This section turns to determining the structure of firms collaborating with consultants for innovation. Unfortunately, the innovation surveys do not discriminate between different types of consultants. We therefore suspect that when answering, firms have in mind all types of consultants that might relate to the invention, developing, prototyping and the marketing stage.

Table 3-21 and Table 3-22 give the parameter estimates of the logit regression and the marginal effects for the significant variables in the reduced models.

Table 3-21. Collaboration with consultants.

	1991				1996				2000			
variable	full		red.		full		red.		full		red	
(Intercept)	–4.6291	***	–4.8283	***	–4.3541	***	–3.861	***	–3.3542	***	–3.3328	***
a.inopc	–0.0089		x		0.1207		x		0.2749		x	
a.mac	–0.177		x		–0.1186		x		0.3297	.	0.3195	.
a.sfbf	0.7923	*	0.9332	**	0.2259		x		0.0557		x	
a.sfinno	0.303		x		0.3583		0.5673	*	–0.8728	.	–0.8466	.
b.conc	0.218		x		–0.3345		x		–0.0307		x	
b.empl	0.4661	***	0.4822	***	0.24	***	0.2218	***	0.4593	***	0.4413	***
b.exsh	0.1595		x		0.1066		x		0.4759	.	0.4899	*
b.lprod	–0.0012		–0.0012	.	0.0013	**	0.0011	**	1e-04		x	
b.orch	0.0626		x		0.2603		x		–0.111		x	
c.hmtm	0.3129		0.4622	.	0.2603		x		0.2396		x	
c.htm	–0.2918		x		0.6885	.	x		–0.7264		–0.8801	*
c.kis	–0.432		x		0.8052	**	0.5514	*	0.3761		x	
c.lmtm	–0.1051		x		0.4219		x		–0.3536		–0.5351	*
c.os	–0.3821		x		–0.4887		–0.7694	*	–0.4496		–0.6036	*
d.rd	–0.1814		x		1.32	.	1.0763		–0.276		x	
d.rddiv	1.465	***	1.4005	***	0.7726	**	0.7495	***	0.8469	***	0.8211	***
e.hampeco	0.2361	.	0.2392	.	–0.0728		x		0.197	**	0.1923	**
e.hampkno	0.0155		x		0.1302	.	0.105	.	0.1593	*	0.1635	*
N					665		665		832		832	
pseudo-R^2					0.206		0.198		0.204		0.194	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 3-22. Marginal effects – collaboration with consultants.

variable	1991	1996	2000
innovation activity – output			
a.inopc			
a.mac			6.41
a.sfbf	15.33		
a.sfinno		11.99	–14.13
characteristics			
b.conc			
b.empl	6.41	4.32	8.99
b.exsh			9.98
b.lprod	–0.02	0.02	
b.orch			
sectoral classification			
c.hmtm	6.65		
c.htm			–14.58
c.kis		11.62	
c.lmtm			–10.06
c.os		–12.79	–10.97
innovation activity – input			
d.rd		16.09	
d.rddiv	18.61	14.60	16.73
hampering factors			
e.hampeco	3.15		3.92
e.hampkno		1.99	3.33

Innovation survey 1991

Companies that have a positive experience of collaboration show a 15% higher probability to collaborate compared with companies that do not share this experience. The size of the company also matters for collaboration with consultants – the larger the company the more likely it is to collaborate with consultants. The labour productivity, though, has a negative effect on the propensity to collaborate with consultants. Concerning the technological intensity, the only sector that stands out is the high-medium-technology manufacturing sector, which has a probability to collaborate with consultants that is about 7% higher than the probability in any other sector. We also find that the diversity of the R&D effort increases the probability to collaborate with consultants. Financial constraints also seem to increase the probability of collaboration with consultants.

Innovation survey 1996

Collaboration with consultants is about 12% more likely for companies that – prior to collaboration – marketed innovation. Conducting R&D increased the probability to collaborate with consultants by about 16%. The diversity of R&D efforts also increased the collaboration probability. The technological intensity in manufacturing, however, is not a significant predictor of collaboration with consultants. In contrast to that, the knowledge-intensive services have a 12% higher probability of collaboration with consultants than the manufacturing sectors have. The other sectors show a markedly reduced probability of collaborating with consultants.

Innovation survey 2000

The investment in new machinery that is related to innovation (mac) increases the probability to collaborate by about 6%. The diversification of the R&D effort (rddiv) increases the propensity to collaborate. The novelty of the innovation (sfinno) decreases the collaboration probability with consultants. The larger and the more export oriented a company is, the more likely the involvement of consultant is in the innovation process. The technological intensity in the manufacturing sectors seems to have an inverted u-shape influence on the probability to collaborate. The companies in the low-medium-technology manufacturing sector (lmtm) have an 11% lower probability to collaborate than companies in the low-technology manufacturing sector and companies in the high-medium-technology manufacturing sector (hmtm). Companies in the high-technology manufacturing sector (htm) also have a reduced probability of collaboration with consultants. In the service sector the knowledge-intensive services (kis) collaborate more with consultants than companies in the other services sectors (os). However, the probability of collaboration in the kis sector is not significantly different from the collaboration probability of the low-technology manufacturing. Both the experienced scarcity of knowledge (hampkno) and the economic constraints (hampeco) increase the probability of collaboration.

Comparison

The only consistent factors influencing the probability to collaborate are the size of the company and the diversification of the R&D efforts. This lends support to hypothesis 1 and to hypothesis 2. Positive past collaboration experience only influences the collaboration probability in 1991. In 1996 and 2000 the past experience with collaboration is not a significant determinant of current collaboration with consultants. Restructuring of the production processes seems to be a reason to collaborate with consultants only in 2000. Organizational change, however, does not have any influence at all. Collaborating with consultants for innovation appears not to be used to accommodate the organizational changes that might be induced by innovation. Consultants also seem not to be employed in the development of innovation to help companies to manage technological complexity. However, based on the line of reasoning above, at least in 2000, the probability of collaboration with consultants increases with the export orientation of companies. This supports hypothesis 24 and leads us to conclude that collaboration with consultants is about the creation and detection of opportunities on international markets. The positive influence of the knowledge scarcity and the simultaneously positive influence of the economic constraints also support the same conclusion.

3.2.4.6 Summary

Table 3-23 and Table 3-24 summarize the results of this analysis.

Table 3-23. Summary of the results I.

Keyword	Variable	exp. Sign	1991	1996	2000
Size	empl	+	√		√
Absorptive capacities	rddiv	+	√		√
Positive experience	sfbf	+			√
Member of group	conc	+			√
Knowledge bottleneck	hampkno	+	√	√	√
Economic bottleneck	hampeco	+	√	√	√
High-tech. sector	htm/hmtm	+			
Special investment	mac	+		√	√
Only proc. innov.	inopc	-		√	
Size	empl	+		√	√
Absorptive capacities	rddiv	+		√	√
Positive experience	sfbf	+		√	√
Member of group	conc	+		√	
Substitution	rddiv/rd	-			
Economic bottleneck	hampeco	+			√
High-tech. sector	htm/hmtm	+			
Knowledge bottleneck	hampkno	+		√	√
Process innovation	inopc/mac	+		√	√
Size	empl	+	√		√
Absorptive capacities	rddiv	+	√	√	√
Positive experience	sfbf	+			√
Member of group	conc	+		√	
Economic risk	hampeco	+		√	√
Incremental innovation	sfinno	-			
Knowledge bottleneck	hampkno	+			
International focus	exsh	+			√

Note: The check marks (√) indicate findings that support the given hypothesis.

Table 3-24. Summary of the results II.

Keyword	Variable	exp. Sign	1991	1996	2000
Size	empl	+	√	√	√
Absorptive capacities	rddiv	+	√	√	√
Positive experience	sfbf	+	√	√	√
Knowledge bottleneck	hampkno	+		√	
High-tech. sectors	htm/hmtm	+	√		
Economic constraints	hampeco	+			√
Size	empl	+	√	√	√
Absorptive capacities	rddiv	+	√	√	√
Positive experience	sfbf	+	√		
Knowledge bottleneck	hampkno	+		√	√
International focus	exsh	+			√
High-tech. sector	htm/hmtm	+			
Organizational change	orch	+			
Restructuring processes	mac	+			√

Note: The check marks (√) indicate findings that support the given hypothesis.

3.2.5 Conclusion

The analysis presented above focuses on the collaborative arrangements of Finnish companies. The findings of this analysis relate to both the data source used and the subject under investigation. The first finding is related to the Community Innovation Survey as a data source. We note that although the CIS can be seen as a major advance compared with the previous data sources, it is far from optimal. It is purely focused on a cross-sectional analysis that causes problems if one wants to look at the dynamic development of firms' innovative behaviour. Further problems in the usage of the CIS occur due to the peculiarities of the questionnaire design, which basically amount to different questionnaires for innovators and non-innovators. At certain stages of the analysis one has the impression that the primary goal for the CIS is statistical production rather than research. The timely coverage of the CIS is particularly unfortunate in the Finnish case as the three waves of the survey do not cover the whole period from 1989 to 2000. The years of the recession in 1992 and 1993 are not covered in the survey. The large benefit of the CIS is to supply internationally compatible data. Second, for both horizontal and vertical collaboration we can tell the story about the building up of absorptive capacities as the probability is positively influenced by the level of diversity in R&D activities. Third, the probability of the collaboration of service sector firms increases over time. Also, fourth, the hypothesis that high-medium-technology manufacturing firms and high-technology firms have a higher propensity to collaborate is not supported by the results here. Fifth, the vertical collaboration propensity of firms belonging to a corporate group of firms decreases between 1996 and 2000. Sixth, vertical co-operation is strongly influenced by experienced bottlenecks in the knowledge domain. Non-vertical collaborations seem not to be influenced so much by the gaps in the knowledge domain. Seventh, in both vertical and non-vertical collaboration the relevance of economic hampering factors on the collaboration is a quite recent phenomenon. Finally, it seems that for managing a certain degree of complexity the vertical collaboration may not be appropriate as the high-technology manufacturing dummy does not have any significant parameter estimates.

4. Ownership innovation activities and performance

Some of the results regarding ownership and performance are also discussed in Ebersberger, Oksanen and Lööf (2005).

4.1 Introduction

In recent years foreign ownership issues have sparked both academic and policy attention. Foreign ownership of domestic companies is an issue on the global scale. Exports from foreign affiliates of multinational corporations represent more than a third of total word trade (Grossman et al. 2003).

The current discussion on the sources and consequences of foreign direct investment starts to highlight the interrelatedness of technology, innovation and, most recently, FDI. Serapio and Dalton (1999), for example, report that the growing FDI investments are closely associated with growing multinational involvement in R&D in foreign affiliates. In recent literature large multinationals are characterized as the main drivers for the globalization of R&D and innovation activities (see for example Garybadze and Reger 1999). However, Patel (1995) has shown that one of the main mechanisms for this globalization of R&D is merger and acquisitions. Change of ownership may have an influence on both the acquiring firm's as well as the acquired firm's innovation activities. This study highlights the differences between Finnish-owned firms and foreign-owned firms in Finland.

The study presented here is structured as follows. In Section 4.2 we elaborate on the key questions posed in this study. In particular, we build on the discussion of the difference between domestic-owned firms and foreign-owned firms and develop some hypotheses about the innovation and technology gaps between foreign-owned firms and domestic-owned firms. Section 4.3 introduces the data and methodology used in the main part of the study. In addition to the two equation selection models we use in the main part of the text, we report the results of a multi-step production function model in Section 4.4.2. Section 4.3.2 presents the empirical analyses, where we get a feeling for the data in an extensive explorative analysis in Sections 4.3.2.1 and 4.3.2.2, followed by the results of the regression models. Section 4.3.3 concludes.

4.2 Key questions

Lipsey (2002) notices that much of the earlier economic literature on foreign direct investment – and subsequently foreign ownership – treats it as a part of the general theory of international capital movements, based on the differences among countries in the endowment and cost of capital. In more recent literature, however, the transmission of technology and knowledge dominates, and partly following Dosi (1988), Porter (1990), Lundvall (1992) and Nelson (1992), the relationship between multinational firms, national innovation systems, geographical proximity, industrial clusters and global networks is discussed; see for example Jaffe et al. (1993), Feldman and Audretch (1995), and Pavitt and Patel (1999). Only if we allow for heterogeneity in institutional arrangements and space, and only if we allow for networks and clusters and the associated effects, we can think about the differences between foreign-owned and domestic-owned companies.

The topic of the present study places it in the broad category of studies relating to the gap between domestic-owned firms and foreign-owned firms, Pfaffermayer and Bellak (2000) and Bellak (2004) provide an extensive overview of the literature relating to the gap hypothesis and distinguish between gaps in profitability, labour relation gaps, productivity gaps, growth gaps and technology gaps, where the productivity gap, the technology gap and consequently the growth gap relate most to the discussion in this study. Given the gap hypothesis, the initial question is: why is it that there is a difference between foreign-owned and domestic-owned firms? Based on theoretical reasoning, we distinguish various types of technology and innovation gaps.

4.2.1 Technology and innovation gaps

The first line of arguments giving rise to technology and innovation gaps relates to firm-specific assets. Multinational firms possess firm-specific assets, such as specific know-how on production processes, reputation, brands or management capabilities (Caves 1996). Those assets are transferable and fully appropriable within the firm, but they are not accessible from outside the firm. The transferability applies to both domestic and foreign affiliates. As such, this theoretic reasoning does not provide an argument for the gaps between domestic and foreign-owned firms; rather, it provides reasoning for a gap between independent firms and firms being part of a corporate group. Activities such as R&D generating firm-specific assets are mostly carried out at the headquarter location (Patel & Pavitt 1999, Markusen 2002, Castellani & Zanfei 2004). Only this observation in combination with the assumption of firm-specific assets leads to a hypothesis for the differential innovation behaviour of domestic and foreign-owned firms. Foreign-owned firms are then more likely to have a lower level of innovation activities than domestic-owned firms. If, however, the firm-specific assets are to be exploited abroad, some adjustments to local habits, regulations and standards may be required. Additional development activities, which are denoted as "asset exploiting" R&D activities (Dunning and Narula 1995), may be required for these adjustments. In this case, R&D and other innovation-related activities are demand-driven as the increased intensity of R&D activities is then the result of the internationalization of sales (see e.g. Vernon 1966, Vernon 1977, Von Zedtwitz and Gassmann 2002). The whole line of arguments leads us to a hypothesis about *innovation input gaps*.

Once again picking up the idea of firm-specific assets which have a pure spill-over nature within the firm, firm-specific assets from the headquarters to the foreign affiliate will increase the companies' innovation performance once the innovation input is controlled for, as the spillovers are not accounted for, resulting in an hypothesis about *innovation output gap*. This innovation output gap is also supported if there are advantages in scale and scope relating to R&D that can be utilized by the foreign-owned company and the multinational network which it is a part of (see Caves 1996 e.g.). Then there is a positive gap, the foreign-owned companies being ahead of the domestic-owned ones. If, however, there is coordination of R&D activities between the foreign headquarters and the affiliate, and the R&D activities are more likely to be carried out at the headquarters location, a negative gap will open up. The previous arguments, however, relate more to companies being part of a corporate group than they relate to the foreign-owned – domestic-owned dichotomy.

Lichtenberg's (1992) matching theory of take-overs posits that some owners better fit to certain firms or establishments than others do. The fit is the major factor in determining the performance of the company or the establishment, and productivity can be used as a proxy for the quality of the fit (Ali-Yrkkö & Ylä-Anttila 2001). The rate of greenfield investment being comparably low, we can think of the ownership change being a means of increasing the productivity of a company. So, foreign-owned firms should, on average, yield a superior performance compared with the domestic firms. This supports the notion of a *productivity gap*. For US and UK data, a productivity gap is found by Girma et al. (2001), Canyon et al. (1999) and Doms and Jensen (1998). Harris and Robinson (2002) find that selecting the high-productivity firms for acquisition results in a superior performance ex post. As previous innovative performance plays a role in the attractiveness to be acquired (Lehto & Lehtoranta 2002), the selection of high-performing innovators for foreign acquisition may be reflected in the superior innovation performance of foreign-owned companies.

Apart from the demand-related issues sketched above, supply side-effects also enter the picture. Large multinational enterprises can better utilize the division of labour in production as well as in research and development (Antràs and Helpman 2003). Supply side-effects relate to the science and technology environment in the host country. Increasing emphasis has been put on these factors recently (Cantwell 1995, Dunning and Narula 1995, Kummerle 1997); strategies focusing on these factors are termed "asset-augmenting" (Dunning and Narula 1995). As for successful innovation, the mastering of an increasing number of technologies becomes vital; the division of labour in research and development enables companies to excel in this respect as the asset augmenting strategy offer access to new and complementary assets. And, by being present on the global market, multinational enterprises have a more comprehensive view of the global market situation (e.g. de Meyer 1993). Hence they are more likely to deliver product innovations to the market. Both Frenz and Ietto-Gilles (2004) and Castellani and Zanfei (2004) find support for a related hypothesis for Italian and UK firms, giving rise to an *innovation output gap*.

When pursuing the asset augmenting strategy, multinational companies can rely on a broader range of partners to build up their assets. It is less costly for them to source knowledge internationally. Given easier access to knowledge, foreign-owned companies are less dependent on sourcing knowledge locally. A *local* *embeddedness gap* would hence state that foreign-owned firms are less embedded in the local or national innovation system. Interaction with domestic partners is supposedly lower for foreign-owned companies. On the other hand, it has been argued that locally-specific factors can be the source of the company's competitive advantage if the heterogeneity of the sources is managed and utilized appropriately (Narula and Zanfei 2004, Furu 1999, Andersson 1997, Hedlund 1986, Kogut 1989). Appropriate management and utilization may result in an increased embeddedness though. Essentially, the underlying hypothesis does not relate to foreign ownership; rather, it relates to multinationality. So, even among the domestic firms, multinational firms should be distinguished. If the foreign-owned affiliate performs a monitoring activity to utilize external scientific knowledge and technological capabilities (see Dunning and Narula 1995, Kuemmerle 1997, Florida 1997), the embeddedness will be positively affected. It then is a direct result of the foreignness of the ownership.

If the local embeddedness hypothesis holds, we may also find a *funding gap*. This may be due to the fact that foreign-owned companies have a larger selection of potential sources they can draw from to finance their innovation activities. As the funding decision is strongly influenced by the potential impact of the funding, the funding is less likely to occur if it can be assumed that the applied project is carried out anyway and financed with the abundance of sources multinationals supposedly have at their disposal.

4.2.2 Home country effects

Even though we observe increasing internationalisation of activities among multinational enterprises, it has been argued that the home country of the companies still matters in determining their internationalization, their strategy and their activities abroad (e.g. Porter 1990, Benito et al. 2002 fig. 1). Pavitt and Patel (1999) and le Bas and Sierra (2001) find that most multinational corporations tend to locate their R&D activities in their home country. Therefore, the national system of innovation of the home country affects their pattern of innovation in their foreign affiliates. This home country may be even more dominant as firms tend to locate their technology abroad in the core areas where they are strong at home.

The division of decision power – amongst other things, the power to shape the strategic orientation of the company – depends on the cultural distance between the home country and the country of the affiliate (Dunning 1993). Traditionally, the literature distinguishes between the German and European system of corporate governance and the Anglo-Saxon system of corporate governance. The differences in the governance style can best be exemplified by looking at control, at corporate goals. Typically, the German and European corporate governance is characterized by a concentrated ownership of listed companies – some argue about the weak minority protection of the German system. Also, companies tend to follow a strategy to maximize the stakeholder value, whereas the Anglo-Saxon system is thought to follow a shareholder value maximizing approach. The Anglo-Saxon system is also characterized by a strong minority protection and dispersed ownership.

The demand-led innovation activities by foreign affiliates discussed above imply a knowledge flow from the home country to the foreign affiliate. The technological level, the expertise and the performance of the affiliate are largely affected by the performance of the company in the home country. Narula and Zanfei (2004) argue that in the case of the asset-exploiting R&D strategy the strategic decisions are rigidly centralized in the headquarters, even increasing the effect the home country culture and governance style has on the innovation activities of the foreign affiliates.

The tacitness of the knowledge of both production and innovation implies that locational proximity matters when transmitting this knowledge from the headquarters to the affiliates and vice versa (Blanc and Sierra 1999).

4.2.3 Selected empirical findings

There is a growing amount of literature on foreign ownership and innovation relying on Community Innovation Survey data; see for example Frenz and Ietto-Gilles (2004), Castellani and Zanfei (2004) and Baclet and Evangelista (2004). As the study below relies on the Finnish Community Innovation Survey, these studies are closest in terms of the data source used.

A common research topic is the innovativeness of foreign-owned firms versus domestic-owned firms. Using a dataset of 1,115 observations from CIS 2, Balcet and Evangelista (2004) show that companies under foreign ownership were more innovative than domestic firms in Italy during the period 1994–1996. The authors explain the greater innovativeness of foreign firms by a larger concentration in the science-based sectors and by being larger in size when compared with domestic firms. However, in the majority of technologically intensive sectors, domestic firms outperform foreign-owned firms, especially in terms of R&D intensity, while an opposite pattern characterizes the medium and low innovative industries. Based on their results, Balcet and Evangelista suggest that the innovation strategies of foreign-owned firms are strongly affected by the strengths and weakness of the innovation systems in the Italian host country; in the case of most science-based and scale-intensive sectors the attractiveness in Italy is low, whereas the foreign-owned firms seem to be attracted by the competencies and know-how accumulated in all traditional and mechanical engineering industries, where Italy holds a clear competitive advantage. Drawing on the same data source as Balcet and Evangelista (2004), Castellani and Zanfei (2004) follow a different methodological approach. Their analysis finds innovation and technology gaps between Italian multinationals and domestic non-multinationals. However, there are no gaps between domestic non-multinationals and foreign-owned firms in Italy.

Frenz and Ietto-Gillies (2004) use a U.K. data set containing 679 observations from CIS 2 and CIS 3 for testing the hypothesis that multinationality per se affects the propensity to innovate. Comparing domestic and foreign-owned firms being part of a multinational versus firms being part of a uninational company, they find that those enterprises which belong to a multinational corporation are more likely to engage in innovation activities, and that this engagement is on continuous basis rather than only occasionally.

4.2.4 Research questions

Based on the discussion in Section 4.2.1 and Section 4.2.2, we can distil a hypothesis about the potential gaps between foreign-owned firms and domestic-owned firms:

Hypothesis IIG: Foreign-owned firms and domestic-owned firms differ in the level of their innovation input (*innovation input gap*).

Hypothesis LEG: Foreign-owned firms and domestic-owned firms differ in the intensity of their embeddedness in the local innovation system (*local embeddedness gap*).

Hypothesis IOG: Foreign-owned firms and domestic-owned firms differ in their innovation output (*innovation output gap*).

Hypothesis PG: Foreign-owned firms and domestic-owned firms differ in the level of their productivity (*productivity gap*).

Hypothesis FG: Foreign-owned firms and domestic-owned firms differ in the propensity to receive public funding for their innovative activities (*funding gap*).

Based on the discussion about differences in governance styles and the home country effect, each of the above hypotheses has to be differentiated so as to refer not only to foreign ownership but also to the different home countries of the foreign-owned firms. In addition to the differentiation of the home countries, the discussion above requires treating domestic multinationals and domestic uninationals differently.

4.3 Data and methodology

In the following section we introduce the data source and the methodology used to test the various gap hypotheses discussed above.

4.3.1 Data

The research questions relate innovation activities to foreign ownership and constitute a facet of the broad topic of the internationalization of R&D. Basically, most of the data sources regarding the internationalization of corporate R&D contain some information with which to analyze the questions at stake. Table 4-1 contains a brief assessment of the available data sources, their strengths and weaknesses.

Table 4-1. Data sources.

Data source	Measure	Strength	Weaknesses	Sources
R&D surveys	Innovation expenditure	Regular and recognised data on main source of technology, large samples	Lacks detail, no output measure, no indicators for motives, etc.	OECD R&D surveys
Patents counts	Patenting activity	Regular detailed & long-term data available by firm, location, industry, technical fields	Uneven propensity to patent amongst countries, sectors and companies; misses software	US PTO EPO
Innovation surveys (CIS)	Innovation input, innovation output, innovation process characteristics, firm characteristics	Systematic data on innovative activities of foreign-owned & domestic firms, homogenous across countries	Cross-section, no panel, sample size, subjective answers	National Sources,
Other ad hoc surveys		Detailed data, e.g. on motivations for conducting foreign R&D	Uneven coverage across countries	Various

Source: based on Patel (2004).

As the analysis looks at innovation activities as such, the analysis heavily depends on the comprehensiveness of the items covered in the data sets. The Community Innovation Survey represents them as data sources. Furthermore, analysing internationally comparable data might facilitate the comparability of similar analyses carried out in other countries.

Community Innovation Survey data is increasingly being used as a key data source in the study of innovation at the firm level in Europe. Within Europe, CIS surveys are usually conducted every five years. The third and most recent wave of the CIS was carried out in 2001. It covers the years 1998 to 2000. CIS surveys follow the 'subject-oriented' approach because they ask individual firms directly whether they were able to produce an innovation. The CIS is widely piloted and tested before implementation and, the questionnaire has been continuously revised since it was first used in the early 1990s. The CIS is based on previous experience of innovation surveys, including the Yale survey and the SPRU innovation database (Klevorick et al 1995, Pavitt, Robson & Townsend 1987). It provides an opportunity to investigate patterns of innovation across a large number of industrial firms.

Although far from being perfect, CIS data does provide a useful complement to the traditional measures of innovation, such as patent statistics, as it covers the innovative efforts of firms, their innovation strategies, their innovation success and, to a certain degree, it enables an assessment of the innovation-induced performance changes of firms. Compared with the R&D and patent data, innovation output indicators in the CIS have the advantage of measuring innovation directly (Kleinknecht et al. 2002). The new indicators in the CIS capture the market introduction of new products and services, and their relative importance for the innovators sales. In addition to the new set of innovation output variables, the CIS data offers internationally comparable data, which, as pointed out above, enables internationally comparative studies, a feature which – with few exceptions, such as Janz et al. (2003), Lööf and Heshmati (2002) or Czarnitzki and Kraft (2004) – has not been utilized extensively.

The dataset used here is the Finnish Community Innovation Survey conducted by Statistics Finland. The third wave of the CIS, which this analysis is based on, was launched in 2001 and refers to the years 1998 to 2000. The survey was sent to 3,462 firms, which yielded a response rate of 50% (Statistics Finland 2002a). The basic descriptive statistics of the variables used can be found in Table 4-2, Table 4-3 and 4-4 below[xxii], where the endogenous and exogenous variables are described and summarized.

4.3.1.1 Methodology and variables used

Although the CIS data set contains sampling weights for the whole data set, we chose not to use the weights for two reasons. First, the sampling weights stratify the sample according to size, industry and innovativeness; they do not refer to foreign ownership. So, using the sampling weights we may even introduce a larger distortion to the sample. Second, it is argued that not weighting the observations is closer to their economic significance (cf. Tether 2001). So, fundamentally, when we speak about Finland or the Finnish firms, we mean the firms in the data set. Regrettably, in being restricted by the available data, we have to leave it open whether or not our findings are representative for the whole economy. However, as suggested by Tether (2001), looking at the economic weight of firms rather than looking at their sampling weight we would argue that the findings of this analysis do represent the differences between foreign-owned and domestic-owned firms.

We have tried to give a most comprehensive picture of the effects foreign ownership has on the innovation activities of firms. We do so by analysing the CIS data sets by means of two econometric setups. First, we employ sample selection models – to be reported below. Additionally, we employ a complete production function model in the vein of Crépon, Duguet and Mairesse (1998) and report the results in Section 4.4.2.

To analyze the hypothesis given in Section 4.2.4 above – depending on the type of the exogenous variable – we use two different, yet quite comparable econometric models. The common idea of the econometric models is that it takes account of the fact that the dependent variable, say the innovation effort, is only observed for innovative companies – companies, that is, which have decided to engage in innovation activities. However, the decision to be innovative is not independent of such firm characteristics such as size, investment activities, foreign ownership, etc. Both the decision about the innovation effort and the decision about the innovation activity have to be modelled simultaneously. If the dependent variable is a continuous variable, we use the Heckman selection model described in equations (1) and (0). If the dependent variable is a dummy variable, we use the Heckman probit model described in (2) and (0).

Heckman selection model

$$z_i^* = \gamma'\mathbf{w}_i + u_i \text{, where } z_i = 1 \text{ if } z_i^*>0,\ z_i = 0 \text{ otherwise} \qquad (0)$$

$$^{c}y_i = \beta'\mathbf{x}_i + \varepsilon_i \text{, where } ^{c}y_{\mathrm{i}} \text{ is only observed if } z_i = 1 \qquad (1)$$

Heckman Probit model

$$z_i^* = \gamma'\mathbf{w}_i + u_i \text{, where } z_i = 1 \text{ if } z_i^*>0,\ z_i = 0 \text{ otherwise} \qquad (0)$$

$$y_i^* = \beta'\mathbf{x}_i + \varepsilon_i \text{, where } ^{d}y_i = 1 \text{ if } y_i^*>0,\ ^{d}y_i = 0 \text{ otherwise} \qquad (2)$$

In equation (0) z_i^* is the unobserved propensity to innovate based on the exogenous company characteristics $\mathbf{w}_i$. z_i is the observed state of the company whether carrying out innovative activities or not. ${}^c y_i$ is a continuous innovation activity variable in equation (1). In equation (2) ${}^d y_i$ is a dummy variable indicating certain innovation activities; $\mathbf{x}_i$ is the vector of exogenous company characteristics determining the ${}^d y_i$. The variables z_i, ${}^c y_i$, ${}^d y_i$, $\mathbf{w}_i$. and $\mathbf{x}_i$ are specified below.

Endogenous variables

Table 4-2 summarizes the endogenous variables used to test the hypothesis discussed in Section 4.2.4. It also contains the variables in the CIS data, which are used to construct the variables. To analyse the innovation input gap we use the various indicators to approximate the innovation input of the firms. First, we use an indicator of whether the company carries out innovation activities at all. The gap hypothesis can be analysed for all firms in the sample. This indicator is also used to estimate the selection equation (0). Second, we use an indicator for the size of the innovation efforts. This and the analyses of all other gaps can only be carried out for those companies that carry out innovation activities. The local embeddedness gap is tested using various indicators, such as embeddedness in the national innovation system, the embedding of the domestic parts of the company's value chain, the companies' embeddedness in the domestic industry structure and the utilization of the domestic science and research environment. The innovation output gap is measured by the patenting behaviour[xxiii] of the firm and by the firm's ability to launch a product innovation, which is new to the market. The productivity gap is assessed by the labour productivity; the analysis of the funding gap utilizes the information whether or not the companies have received public funding.

Table 4-2. Endogenous variables.

Hyp,	Endogenous variable	… approximated by …	…constructed using the CIS variables	Mean
IIG	Innovation activity	Product innovation or process innovation or ongoing R&D project (dummy)	inpdt, inpcs, inon	0.630
IIG	Innovation input	Innovation effort per worker (log)	rtot, emp	0.720
LEG	Embeddedness in the domestic innovation system	Domestic collaboration for R&D (dummy)	co$i$1 $i \in \{1 \ldots 8\}$	0.427
LEG	Embedding of the domestic value chain	Vertical domestic collaboration for R&D (dummy)	co21, co31	0.355
LEG	Embeddedness in the domestic industry	Horizontal domestic collaboration for R&D (dummy)	co41	0.096
LEG	Embeddedness in the domestic science base	Collaboration with domestic universities or research institutes (dummy)	co71, co81	0.337
IOG	Patent behaviour	Patent application (dummy)	paap	0.258
IOG	Quality level of innovation	Product new to the market (dummy)	inmar	0.417
IOG	Innovation output	Sales from new/modified products per worker (log)	turning, turn, emp	1.549
PG	Productivity	Sales per worker (log)	turn, emp	4.987
FG	Funding	Public funding (dummy)	funloc, fungmt	0.364

Exogenous variables

Based on the discussion above, we expect that the home country of the corporate group matters in determining the innovation activities of the firms. Hence we include information about the home country of the corporate group in the analysis. Ex ante, we build country groups, which are supposed to yield similar corporate governance styles. We group together companies that are part of Anglo-Saxon-owned corporate groups, including UK-owned, US-owned, Irish, Canadian and South African corporate groups. As Finland is embedded in the group of Nordic countries, so we group Danish, Finnish, Icelandic, Norwegian and Swedish-owned companies into this category. All other home countries in the sample are grouped into the European and others category, where European countries clearly prevail. In estimating the selection equation, and in the descriptive statistics below, we differentiate between foreign-owned and domestic-owned companies. Within the domestic-owned companies we differentiate the domestic-owned companies and companies that are a part of a domestic-owned multinational group. As all companies in the sample belong to a corporate group, companies that are not part of a domestic-owned multinational are supposed to be groups with only domestic facilities.[xxiv] Table 4-3 and 4–4 summarize the exogenous variables used in the selection models.

Table 4-3. Exogenous variables for the selection equation (0).

Variable	Mean
Foreign ownership	0.225
Size (log employment)	4.667
Productivity (log labour productivity)[1]	4.987
Significant market area – local (dummy)[0]	0.178
Significant market area – regional (dummy)	0.322
Significant market area – global (dummy)	0.500
Established (dummy)	0.073
Merged (dummy)	0.137
Human capital (share of highly educated empl)	0.355
Tangible investment (log)	1.518
High-technology manufacturing sector (dummy)	0.053
Medium-high-technology manuf. sectors (dummy)	0.211
Medium-low-technology manuf.sectors (dummy)	0.147
Low-technology manufacturing sectors (dummy)[0]	0.200
Knowledge-intensive services (dummy)	0.170
Other services (dummy)	0.219

Note: [0]variable used as a reference category [1]variable not in regression for the productivity gap hypothesis.

Table 4-4. Exogenous variables for the regressions of equation (1) and (2).

Variable	Mean
Domestic non-multinational (dummy)	0.661
Domestic multinational (dummy)	0.114
Nordic multinational (dummy)	0.088
Anglo-Saxon multinational (dummy)	0.066
European multinational or other (dummy)	0.071
Size (log employment)	0.720
Innovation input per worker (log)[1]	4.667
Significant market area – local (dummy) [0]	0.178
Significant market area – regional (dummy)	0.322
Significant market area – global (dummy)	0.500
Product-oriented innovation strategy (dummy)	0.079
Process-oriented innovation strategy (dummy)	0.032
Continuous R&D (dummy)	0.440
Public funding (dummy)	0.364
High-technology manufacturing sector (dummy)	0.053
Medium-high-technology manuf. sectors (dummy)	0.211
Medium-low-technology manuf. sectors (dummy)	0.147
Low-technology manufacturing sectors (dummy)[0]	0.200
Knowledge-intensive services (dummy)	0.170
Other services (dummy)	0.219
Agriculture food and fishery (dummy)	0.661
Oil and gas sector (dummy)	0.114

Note: [0]variable used as a reference category [1]variable not in regression of the innovation input.

4.3.2 Empirical analysis

This section presents the results of the empirical analysis. In Section 4.3.2.1 we report the descriptive statistics for all firms; in Section 4.3.2.2 we concentrate on the innovative firms; in Section 4.3.2.3 we finally report and discuss the results of the sample selection models testing the gap hypothesis.

As this analysis endeavours to establish the difference between foreign-owned and domestic-owned firms, we restrict the firms in our sample to the firms belonging to a corporate group.[xxv]

Determining the home country of the company

The grouping for the home country variable in the analysis is basically distilled from two variables in the CIS questionnaire. The first question asks about whether or not the surveyed company is part of a corporate group. We select only those companies answering this question positively. We drop companies giving no answer or a negative answer. The second variable used contains the information about the home country of the company. We drop all companies where no country code is given.

We distinguish the domestic-owned companies in companies belonging to domestic-owned corporate groups and domestic-owned domestic groups. As there is no variable in the CIS indicating the multinationality of domestic groups, we have to derive this information from other details in the questionnaire. In the CIS questionnaires innovative companies are asked about their collaboration partners for R&D by the location of the collaboration partner. If a domestic-owned company reported innovation collaboration within the corporate group but outside the home country, we regarded the company as a domestic-owned multinational company. This procedure clearly underestimates the number of domestic-owned multinational companies. However, if we find a significant influence of the multinationality on innovation activities, we are on safe ground as the control group of domestic-owned companies also contains companies, which are domestic multinationals.

4.3.2.1 Descriptive statistics for all firms

The descriptive statistics in this section includes all firms in the sample regardless of their carrying out innovative activities.

Table 4-5. Sample distribution.

	Observ. Total	Innov. firms	Percent
Total observations	818	515	63.0
D: Domestic non-multinationals	541	303	56.1
D-M: Domestic multinationals	93	93	100.0
N-M: Nordic multinationals	72	47	65.3
AS-M: Anglo-Saxon multinationals	54	40	74.1
EU-M: European and other multinationals	58	32	55.2
DOM: Domestic-owned firms	634	396	62.5
FOR: Foreign ownership	184	119	64.7

Note: This table is based on the sample of firms that are a part of a corporate group. Innovative firms are firms reporting a product and/or process innovation and/or report ongoing innovation activities. The innovators' share of 100% of the domestic multinationals is due to the construction of the domestic multinational indicator (See Section 4.4.1).

Table 4-5 contains the distribution of the companies across the country groups. We also report the number of innovators. We define companies that exhibit innovation activities – such as having introduced a product or process innovation or companies that are still committed to ongoing R&D projects – as innovators. Companies that have abandoned an R&D project and are not currently undertaking innovation activities, or have not launched a product innovation or process innovation, are not considered innovation-active.

In the Finnish context we observe that well over 60% of the companies carry out innovation activities. Domestic non-multinationals[xxvi] and European multinationals contain a below average fraction of innovative companies, whereas the Anglo-Saxon-owned companies show the highest rate of innovation-active companies. The fraction of innovation-active companies among the foreign-owned companies does not differ from the share of innovative companies among the domestic-owned companies.

Table 4-6. Summary statistics of firm characteristics and innovation activities.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
Size	316	1835	165	218	162	539	180
Sales	9.356	11.308	9.458	10.065	9.640	9.642	9.694
Labour prod.	4.846	5.245	5.121	5.496	5.242	4.905	5.269
Exports	2.270	4.061	3.059	3.976	2.945	2.532	3.292
Investment	1.519	1.989	1.117	1.747	1.030	1.588	1.275
Innov. input	0.471	1.762	0.582	1.487	0.818	0.661	0.922
Innov. prod.	1.164	3.270	1.623	2.391	1.511	1.473	1.813

Note: The table reports the averages of the firms' main economic characteristics and innovation activities. All categories except the size are in logs.

Table 4-6 shows the summary statistics of firm characteristics and behaviour for all five national groups and the foreign-owned and domestic-owned groups. The summary shows that, on average, domestic-owned multinational companies are larger than any of the other companies. This is not surprising as the foreign-owned multinationals are subsidiaries. Most probably, some part of the surveyed domestic multinational companies are headquarters, although there is no indicator in the data whether the surveyed company is a subsidiary or a headquarters of a group. A large fraction of headquarters in this group explains the size difference. In terms of investment and exports, domestic multinationals are quite similar to Anglo-Saxon-owned firms.

Domestic multinationals not only excel in terms of size, they also excel in terms of innovation input and innovation output measured by the innovation effort per employee and by the sales from new (and significantly modified) products per employee respectively. Also, the innovation input and the innovation output of the Anglo-Saxon-owned firms exceeds the respective performance of all of the other foreign-owned companies and domestic mononationals. Here we would argue in favour of an innovation input and an innovation performance gap. However, for a more convincing analysis we have to control for various other effects, as the country groups are not comparable in terms of the various company characteristics and the sectoral composition. Additionally, we need to investigate whether the gaps are caused by differences in the likelihood of carrying out innovative activities, or the gap is caused by different innovation intensity. However, at this stage we see some indication of potential innovation and technology gaps.

Table 4-7. Sectoral distribution with ownership categories in percentages.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
HI M	4.2	9.7	1.4	16.7	1.7	5.1	6.0
HM M	14.6	42.0	22.2	33.3	36.2	18.6	29.8
LM M	20.0	14.0	8.3	11.1	10.3	19.1	9.8
LO M	14.4	9.7	20.8	16.7	15.5	13.7	17.9
KIS	22.4	20.4	23.6	7.4	5.2	22.1	13.0
OS	24.4	4.3	23.6	14.8	31.0	21.5	23.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: The sectors are defined along the lines of the OECD classification of knowledge intensity: high-technology manufacturing (HI M), high-medium-technology manufacturing (HM M), low-medium-technology manufacturing (LM M), low-technology manufacturing (LO M), knowledge-intensive services (KIS) and other services (OS). See Hatzichronoglou (1997).

Table 4-7 summarizes the distribution of the companies across the classes of knowledge-intensive sectors as defined by Hatzichronoglou (1997) and OECD (2001). Anglo-Saxon ownership is mostly concentrated in (medium) high-technology manufacturing and less concentrated on services. With the exception of medium-low-technology manufacturing and high-technology manufacturing, Nordic multinationals are equally spread across the sectors. Domestic multinational companies are predominantly concentrated in the medium-high-technology manufacturing. Generally, we observe that foreign-owned companies are more concentrated in the high-medium-technology manufacturing than domestic-owned companies are.

Table 4-8. Firms' most significant market.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
Local	25.51	1.08	4.17	0.00	6.90	21.92	3.80
National	47.87	21.51	63.89	44.44	48.28		44.01
Global	26.62	77.42	31.94	55.56	44.83	34.07	42.93
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: The table reports the share of firms in percentages.

In Table 4-8 we summarize what companies report as their most significant market. The most striking, yet not unexpected, difference between foreign-owned and domestic-owned companies is that the former concentrate less on local markets than the latter. Still, the focus on national markets by all foreign-owned companies is strikingly high. On average, more than 50% of the firms argue that their most important market is local or national. This focus is even more striking given the small size of the national market. If companies follow an asset-exploiting strategy, we would certainly find a strong focus on local and national markets. The most internationally-oriented companies are the domestic multinationals. More than three-quarters of those firms regard the international markets as most important for them. They are followed by the Anglo-Saxon-owned companies, where more than half of the sample focuses on global markets. Nordic-owned companies, however, focus on national markets more than any of the other group.

4.3.2.2 Descriptive statistics for the innovative firms

The descriptive statistics in this section only focus on innovative companies as defined above. This gives a more detailed picture of the firm's innovative strategies and the related activities. Table 4-9 gives the percentage of firms where the given activity can be observed. Hence it summarizes how pervasive the activity is among the innovative companies; it does not give an indication of the intensity of the innovation activity.

Table 4-9. Innovation activities.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
Innovation expenditure	96.7	98.9	93.6	100.0	100.0	97.2	97.5
Innovation sales	73.6	94.6	80.9	87.5	81.3	78.5	83.2
Product innovation	75.2	94.6	83.0	90.0	81.3	79.8	84.9
Process innovation	49.2	77.4	46.8	57.5	43.8	55.8	49.6
Continuous R&D	61.4	95.7	53.2	87.5	78.1	69.4	71.4
Public R&D funding	52.5	87.1	38.3	70.0	34.4	60.6	47.9

Note: The table gives the share of firms in percentages where the respective innovation activities can be observed.

Not surprisingly, almost all innovative firms – in our case here more than 97% – report innovation expenditure. However, on average, only less than 80% of the companies report positive sales from new or significantly modified products. The fraction of companies reporting the introduction of new or significantly modified products almost equals the fraction of companies reporting positive sales generated by those products. Domestic multinationals report by far the largest fraction of process innovations, which can probably be explained by the larger size of the average company in this category. Domestic non-multinationals and foreign-owned companies have a similar propensity to launch process innovations. Only Anglo-Saxon-owned companies stand out with an above-average fraction of process innovations.

With regard to continuous R&D, the domestic multinationals and Anglo-Saxon-owned companies stand out. More than four out of five companies are involved in R&D activities on a continuous basis. Only about one in two Nordic-owned companies show continuous R&D. We also observe that the propensity to receive public funding differs between the country groups. Public funding for R&D is a quite ubiquitous phenomenon among domestic multinationals. So it is for the Anglo-Saxon-owned multinationals. Nordic and European-owned firms reveal a far lower propensity to receive public funding, which is considerably lower than the propensity of domestic non-multinationals. The sectoral composition of the foreign engagement and the existence of technology programmes targeted at fostering certain sectors may explain some of the variation observed here. However, it cannot account for the large differences between Anglo-Saxon on the one side and European and Nordic-owned companies on the other.

On the basis of the innovation activities, the average Anglo-Saxon-owned company is most similar to the domestic multinational. The innovation activities of the Nordic-owned companies and the European-owned companies are most similar to the domestic non-multinationals.

Table 4-10. Methods of protection.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
Patent (Valid)	34.0	71.0	53.2	65.0	40.6	42.7	53.8
Patent (Application)	27.7	72.0	34.0	50.0	31.3	38.1	38.7
Design patterns	13.9	34.4	31.9	22.5	15.6	18.7	24.4
Trademarks	27.1	67.7	55.3	42.5	31.3	36.6	44.5
Copyright	12.5	31.2	23.4	20.0	15.6	16.9	20.2
Secrecy	55.1	84.9	66.0	72.5	50.0	62.1	63.9
Complexity of design	34.3	49.5	34.0	47.5	15.6	37.9	33.6
Lead-time advantage	59.1	74.2	66.0	67.5	46.9	62.6	61.3

Note: The table gives the share of firms indicating the use of the respective methods of protection.

The CIS questionnaire also enquires about the firms' assessment of certain methods to protect inventions and innovations. Firms are also asked whether they already hold valid patents and whether or not they have applied for patents in the years 1998 to 2000. Table 4-10 contains the percentage of firms giving positive answers to the respective questions in the questionnaire. Here it can be seen that domestic multinationals are more likely to possess valid patents and to apply for patents. It also shows that domestic multinationals are more likely to use either of the given protection mechanisms. Informal protection methods, such as lead-time advantages and secrecy, are most favoured, whereas formal protection mechanisms are least favoured. Among the formal protection methods, patenting plays a leading role. The ranking of the preferences does not differ between domestic-owned and foreign-owned companies. Neither does it differ between the country groups. However, it becomes obvious that there are group-specific differences in the rate of usage of the protection mechanisms. The Anglo-Saxon-owned firms again most resemble the domestic multinationals. The European multinationals are most similar to the domestic mononationals

Table 4-11. Innovation Input and Innovation Output.

	D	D-M	N-M	AS-M	EU-M	DOM	FOR
Input							
Mean	6.1	9.1	3.0	10.0	8.5	6.8	6.9
Std.dev	14.9	15.7	5.8	21.1	16.7	15.2	15.6
Min	0.0	0.0	0.0	0.2	0.1	0.0	0.0
Max	100.0	100.0	35.6	100.0	75.3	100.0	100.0
Output							
Mean	16.2	25.6	15.6	25.9	18.8	18.4	19.9
Std.dev.	23.6	27.5	20.1	27.8	21.7	24.9	23.6
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	100.0	100.0	80.0	100.0	80.0	100.0	100.0

Note: This table reports the summary statistics for the innovation expenditure (input) as a fraction of sales and the fraction of turnover generated by new or significantly modified products (output). All values are percentages.

Table 4-11 summarizes the innovation input and the innovation output of the innovating firms. The innovation input is measured by the fraction of sales spent on innovation activities. The innovation output is represented by the sales from new and significantly modified products relative to total sales. On average, domestic multinationals and Anglo-Saxon-owned firms seem to show a similar pattern of innovation input and innovation output. Both invest about 10 per cent of the sales in innovation and the fraction of sales both realize from selling new or significantly modified products amounts to more than a quarter. On average, domestic non-multinationals and both Nordic-owned and European-owned companies show similar behaviour, although the Nordic-owned companies reveal the lowest innovation expenditure relative to sales.

Relating the summary statistics found in Table 4-11 to the gap hypothesis, and disregarding any statistical significance issues, we can assert an innovation input gap between Anglo-Saxon-owned firms and domestic non-multinationals. We also find an innovation input gap between the domestic multinationals and the domestic mononationals, the Nordic multinationals and the European multinationals. There also seems to be an innovation input gap between the Anglo-Saxon-owned firms and the other foreign-owned firms. The innovation output gap follows the same pattern.

Table 4-12. Co-operation on innovation.

		D	D-M	N-M	AS-M	EU-M	DOM	FOR
Within the group	D	41.9	74.2	21.3	15.0	12.5	49.5	16.8
	G	0.0	-[1]	48.9	57.5	53.1	23.5	52.9
Suppliers	D	37.0	77.4	40.4	37.5	31.3	46.5	37.0
	G	22.4	64.5	40.4	35.0	21.9	32.3	33.6
Customers	D	35.0	81.7	55.3	37.5	31.3	46.0	42.9
	G	16.8	78.5	23.4	40.0	25.0	31.3	29.4
Competitors	D	11.9	34.4	6.4	12.5	9.4	17.2	9.2
	G	7.3	19.4	10.6	12.5	9.4	10.1	10.9
Consultancies	D	26.4	53.8	23.4	30.0	21.9	32.8	25.2
	G	8.3	24.7	17.0	17.5	9.4	12.1	15.1
Priv. R&D Labs	D	24.4	59.1	17.0	32.5	28.1	32.6	25.2
	G	6.9	32.3	6.4	10.0	15.6	12.9	10.1
Universities	D	38.0	92.5	31.9	55.0	40.6	50.8	42.0
	G	6.3	38.7	10.6	22.5	6.3	13.9	13.4
Public R&D Org.	D	25.4	64.5	23.4	32.5	21.9	34.6	26.1
	G	5.6	35.5	4.3	7.5	9.4	12.6	6.7
Domestic								
– collaboration		59.1	98.9	70.2	70.0	53.1	68.4	65.5
– vertical coll.		46.5	91.4	59.6	55.0	43.8	57.1	53.8
– horizontal coll		11.9	34.4	6.4	12.5	9.4	17.2	9.2
– scientific coll.		41.9	95.7	38.3	65.0	46.9	54.5	49.6

Note: This table gives the percentage of companies reporting collaborative innovation efforts with the respective partners. D denotes domestic partners and G denotes international partners. The diversity index is the number of partners currently used relative to the number of potential partners. For the diversity index, the table reports the means. [1]The way we defined domestic multinationals causes the global co-operation rate to be 100 per cent.

Table 4-12 shows the collaboration pattern for innovation broken down by country groups and the internationality of the collaboration partner. Regardless of the ownership, Finnish domestic universities are among the most important collaboration partners. Only Nordic-owned companies use Finnish universities less than vertical collaboration partners, such as domestic suppliers and domestic customers. International collaboration within the group is a major part of the innovation activities for all foreign-owned companies. The diversity of the set of collaboration partners does not differ for the foreign-owned companies and the domestic groups. However, domestic-owned multinationals seem to maintain a broader network of collaboration for R&D than the other firms do.

In the lower part of Table 4-12 we see a local embeddedness gap between Anglo-Saxon-owned and Nordic-owned companies and the domestic non-multinationals and the European-owned firms. The domestic multinationals show the deepest embedding in the domestic system of innovation. The integration of domestic suppliers and customers in the innovation process is more common in domestic multinationals than in any other group; however, it shows that the Anglo-Saxon-owned companies and Nordic-owned companies maintain a higher involvement of suppliers and customers than the European-owned companies and domestic non-multinationals. Embeddedness in the domestic industrial environment, as measured by the horizontal collaboration for R&D, is equally low for foreign-owned companies, with the Nordic-owned companies being the least embedded. The domestic multinationals enjoy the deepest embedding. The embeddedness in the domestic science system reveals a gap between the domestic multinationals and the other companies, where the Anglo-Saxon-owned companies seem to be more deeply embedded than both the Nordic-owned, the European-owned and the domestic-owned companies.

The summary of the co-operation for innovation reveals an embeddedness gap between the domestic multinationals and all other Finnish companies. There is also a gap between the Anglo-Saxon-owned companies and the other foreign-owned companies. We cannot see a clear indication for an embeddedness gap between the domestic-owned companies and the other foreign-owned companies.

4.3.2.3 Regression results

As discussed in Section 4.3.1.1 above, we estimate the effect of foreign ownership and the effects of different underlying governance styles or home countries by means of sample selection models, which allow us to distinguish the decision to be innovation active – i.e. to carry out innovation activity at all – from the decision about the level and the characteristic of the innovation activities.

4.3.2.3.1 Innovation input gap

The selection equation[xxvii] reported in Table 4-13 estimates how the innovation decision depends on exogenously-given firm characteristics and firm behaviour.

The most striking result here is that for Finnish firms, foreign ownership does not have an influence on the decision to innovate. However, we see that the innovators are larger; they command a higher endowment of human capital, maintain larger investments and enjoy higher labour productivity. On average, recent events in the firm history, such as mergers or establishment, do not affect the decision to be innovation-active. The key finding here is that ownership does not matter in determining whether or not to be innovation-active. What does matter, though, is the market orientation of the company. Companies focusing on national and global markets are more likely to carry out innovation activities than companies focusing on local markets. The marginal effects[xxviii] show that the focus on global markets has a stronger effect on the probability to innovate than the focus on the national market.

Table 4-13. Innovation decision (selection equation).

	Innovation activities (IIG)		
	Coeff.		Marg. eff.
Foreign ownership	–0.115		–0.044
Size	0.223	***	0.086
Local markets	Reference		
National markets	1.144	***	0.282
Global markets	0.789	***	0.372
Labour productivity	0.167	***	0.051
Recently established	–0.004		0.012
Recently merged	–0.125		–0.025
Human capital	0.361	*	0.068
Investment	0.096	***	0.023
Constant	–0.115		–
Est. method	HR		

Note: This table reports the results of the selection equation for innovation activities regression using the Heckman selection model. It reports the estimated coefficients and the marginal effects. The related gap is given in parentheses. *** (**,*) indicates significance at the 1% (5%, 10%) level.

Table 4-14 and 4-15 report the results of regressing the innovation activities in order to assess the innovation and technology gaps. The domestic multinationals, the Anglo-Saxon and the European-owned firms have a significantly higher innovation effort per employee than firms in the domestic or Nordic groups. In the innovation decision, we find no indication for an innovation input gap. Once a company decides to carry out innovation activities, we find an innovation input gap. Domestic non-multinationals and Nordic-owned firms lag behind in innovation effort measured in innovation expenditure per worker. Domestic multinationals, Anglo-Saxon-owned firms and European-owned firms spend significantly more resources per worker on innovation activities than the domestic non-multinationals and the Nordic-owned firms.

4.3.2.3.2 Embeddedness gap

Domestic collaboration is more likely among domestic multinationals and Nordic multinationals than among all the other foreign-owned companies. A similar pattern is observed for vertical domestic collaboration. However, it is only the domestic multinationals that collaborate significantly more frequently with competitors. Also, everything else being equal, domestic multinationals are more embedded in the national science system than all the other companies. Hence there is a strong embeddedness gap between domestic multinationals and domestic non-multinationals. We can also conclude an embeddedness gap between the Nordic-owned firms and the domestic non-multinationals. A higher degree of embeddedness with vertical partners seems to be the source of the deeper overall embeddedness. Yet we observe from the regressions that the market the companies focus on is a more significant determinant for their embeddedness in the domestic NIS than the nationality of their ownership.

The more remote from local markets the most important markets are located, the smaller the propensity to collaborate with domestic partners becomes. This holds true for domestic collaboration as such, as well as for all the collaboration types we look at. The product innovation strategy also has a significant impact on the vertical and horizontal collaboration. This again strengthens the point that strategy rather than foreign ownership matters for the utilization of the domestic national innovation system. At this stage of the discussion we see that headquarters as well as the strategy matters to determine the innovation activity of firms.

Table 4-14. Innovation activities, two equation selection models.

	Innovation input per worker (IIG)	Domestic collab. (LEG)	Domestic vertical collab. (LEG)	Domestic horizontal collab. (LEG)	Utilization of dom. science system (LEG)
D			Reference		
D-M	0.510 ***	1.521 ***	1.023 ***	0.608 ***	1.493 ***
N-M	0.234	0.560 ***	0.551 ***	–0.244	0.220
AS-M	0.471 **	0.023	0.067	0.148	0.382
EU-M	0.445 *	–0.048	0.095	0.071	0.337
Innov. input	0.000	0.140 ***	0.066 *	0.106 *	0.200 ***
Size	–0.413 ***	0.146 ***	0.088 ***	0.094	0.188 **
Local markets			Reference		
Reg. markets	–0.131	–0.527 ***	–0.434 ***	–0.646 **	–0.547 **
Glob. markets	–0.232	–0.614 ***	–0.694 ***	–0.861 **	–0.884 ***
Product orient.	0.723 ***	0.220	0.400 *	0.567 **	–0.088
Process orient.	1.247 ***	–0.109	0.450	–0.512	–0.532
Contin. R&D	1.046 ***	0.346 **	0.163	0.287	0.487 ***
Publ. funding	0.623 ***	0.429 ***	0.122	0.252	0.805 ***
Constant	2.082 ***	-	-	–1.129	–0.775
Wald test	259.3 ***	226.63 ***	90.69 ***	52.87 ***	80.70 ***
LR test	12.7 ***	0.31	15.43 ***	1.55 ***	1.73
Est. method	HR	HP	HP	HP	HP

Note: The table gives the coefficient estimates, *** (**,*) indicates significance at the 1% (5%, 10%) level. The estimation methods are indicated as HR (regression model with sample selection) and HP (probit model with sample selection). 6 sector dummies included in the regression are not reported here. The results of the selection equation are not reported here. The Wald statistic tests joint significance and the LR tests the correlation of the two equations. The related gap is given in parentheses.

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Table 4-15. Innovation activities, two equation selection models (continued).

	Patent application (IOG)	Products new to the market (IOG)	Returns to innovation per worker (IOG)	Labour productivity (PG)	Public funding (FG)
D			Reference		
D-M	0.412 **	0.900 ***	0.534 **	0.131	0.528 ***
N-M	0.367 *	0.100	0.391	0.140	–0.211 **
AS-M	0.079	0.159	0.675 **	0.314 **	0.069
EU-M	–0.115	0.172	0.538 *	0.155	–0.542 ***
Innov. input.	0.243 ***	–0.006	0.150 ***	0.146 ***	
Size	0.137	0.067	–0.199 ***	–0.029	0.001
Local markets			Reference		
Reg. markets	0.171	0.643 ***	–0.643 **	–0.257 *	–0.281 ***
Glob. markets	0.322	0.718 ***	–0.577 *	–0.238	–0.123
Product orient.	0.091	0.596 **	1.368 ***	–0.214	–0.228
Process orient.	0.065	0.213	0.275	–0.152	0.811 ***
Contin. R&D	0.384 **	0.167	–0.132	–0.082	0.370 ***
Publ. funding	0.410 ***	0.332	–0.164	–0.142 *	
Const	–1.908	–1.718	4.453 ***	6.040 ***	0.505
Wald test	44.1 ***	116.4 ***	90.5 ***	112.1 ***	56.1 ***
LR test	1.1	3.7 **	24.5 ***	27.6 ***	6.2 **
Est. method	HP	HP	HR	HR	HP

Note: The table gives the coefficient estimates, *** (**,*) indicates significance at the 1% (5%, 10%) level. The estimation methods are indicated as HR (regression model with sample selection) and HP (probit model with sample selection). 6 sector dummies included in the regression, not reported here. The results of the selection equation are not reported here. The Wald statistic tests joint significance and the LR tests the correlation of the two equations. The related gap is given in parentheses.

4.3.2.3.3 Innovation output gap

Nordic and domestic multinationals tend to patent more frequently than other companies. The more intensive patenting behaviour of the domestic multinationals can be explained by a headquarters effect. We also find that public funding induces patenting. The likelihood to innovate on a higher level depends more on market strategy and innovation strategy than the ownership. Only domestic multinationals produce high-level innovations more frequently than domestic groups. Multinationality seems to foster the development of market novelties. By and large, we find no significant innovation output gap between foreign-owned and domestic-owned companies.

Although foreign ownership does not matter for the development of high-level innovation, it does have an effect on the innovation output as measured by the sales of new and significantly modified products relative to total sales. The Anglo-Saxon-owned and the European-owned companies perform significantly better than companies owned by domestic groups. Again, we find that Nordic-owned companies do not differ from domestic-owned ones. For domestic-owned companies, multinationality does matter though. Astonishingly, the return to innovation decreases the more remote the companies' markets are from local markets. Product innovation strategy, however, has a large positive effect on the innovation return.

4.3.2.3.4 Performance gap

Measuring performance by productivity, we find the Anglo-Saxon-owned companies outperforming all the other companies. Innovation input has a positive effect on the performance of the companies. Here we find a performance gap between foreign-owned companies and domestic-owned companies, regardless of their multinationality. At first sight, this result complies nicely with the argument that the Anglo-Saxon governance style focuses on measurable short-term results, which, in turn, would lead to strong investment behaviour and a reduction in personnel, resulting in high labour productivity. It also nicely confirms the argument that Anglo-Saxon-owned companies are Anglo-Saxon-owned because of their high performance. Although the above analysis takes various factors into account to control for exogenous influences, it does not take into account that innovation output may determine the labour productivity and vice versa. The high innovation output of the Anglo-Saxon-owned companies may well determine the high labour productivity. To test this relationship we estimate a production function model in the vein of Crépon, Duguet and Mairesse (1998) and report the results in Section 4.4. The estimation of the model shows that once we control for mutual determination of innovation output and labour productivity, we do not find a productivity gap for the Anglo-Saxon companies; rather, we find a productivity gap for the Nordic-owned companies. Still, the innovation output gap for the Anglo-Saxon-owned companies remains.

4.3.2.3.5 Funding gap

The receipt of public funding for R&D is more likely for domestic multinationals than for companies that are part of a purely domestic group. On average, with exception of the Anglo-Saxon-owned companies, foreign-owned companies are less likely to receive public funding than their domestic Finnish counterparts. We conclude that there is a funding gap. More research needs to be conducted to find the underlying mechanisms for the gap and to assess the impact of the gap on the innovation activities of foreign-owned firms in Finland.

4.3.3 Conclusion

In the previous analysis we first extended the current discussion about gaps between domestic-owned and foreign-owned firms into a more detailed picture of innovation and technology gaps. Mainly theoretical considerations led us to differentiate innovation input gaps, innovation output gaps, local embeddedness gaps, productivity gaps and funding gaps. The empirical analysis utilizes the Finnish Community Innovation Survey covering the years 1998 to 2000. The analysis of the gap hypothesis started with an exploratory analysis of the data, where we already find slight indications pointing to differential behaviour of foreign-owned and domestic-owned firms. The econometric analysis mainly consisted of sample selection models that take the companies' decision whether or not to engage in innovation activities into account.

As the previous literature does not offer a consistent picture of innovation and technology gaps, this paper is clearly in line with the current empirical literature.

The picture we are drawing in this study is not undivided. Depending on the type of indicator we use for innovation input, innovation output and the local embeddedness, we find support for the gap hypothesis. By and large, we would support the innovation input gap hypothesis, the innovation output gap hypothesis, the local embeddedness gap hypothesis, the productivity gap hypothesis and the funding gap hypothesis. The gap hypotheses are not unanimous among the country groups of ownership. The Nordic-owned companies seem to be the most similar to the domestic-owned mononationals, although they reveal a stronger embedding in the local environment and a stronger preference for patenting. European-owned companies exhibit higher innovation input and innovation output, achieved by a significantly lower propensity to receive public funding. The Anglo-Saxon-owned companies also reveal a higher innovation input, which they translate into increased innovation output. Whether or not Anglo-Saxon companies are found to be able to translate the higher innovation output into higher labour productivity depends on the econometric methodology used. The most appropriate modelling shows that Anglo-Saxon companies do not translate the higher innovation input into a better productivity. Table 4-16 summarizes the findings of the study.

Although we found some influence of ownership on the innovation activities of the firms, the most robust result in the analysis is that the market strategy of the companies, such as a focused market, is a stronger determinant for the level of innovation activities than the ownership is.

Table 4-16. Findings of the study.

Gap,	Indicator	Section	Finding	Gap hypothesis supported?
IIG	Innovation activity	4.3.2.3.1	–	no
IIG	Innovation input	4.3.2.3.1	Domestic multinationals, Anglo-Saxon-owned companies and Nordic-owned companies have a higher innovation effort per worker.	yes
LEG	Embeddedness in the domestic innovation system	4.3.2.3.2	Domestic multinationals and Nordic-owned companies reveal a higher collaboration probability with domestic partners.	yes
LEG	Embeddedness in the domestic value chain	4.3.2.3.2	Domestic multinationals and Nordic-owned companies reveal a higher collaboration probability with domestic vertical partners.	yes
LEG	Embeddedness in the dom. ind.	4.3.2.3.2	Domestic multinationals have a higher propensity to collaborate with competitors.	no
LEG	Embeddedness in the dom. science system	4.3.2.3.2	Domestic multinational have a higher propensity to collaborate with domestic universities and research institutes.	no
IOG	Patent behaviour	0	Domestic multinationals and Nordic-owned companies reveal more frequent patenting.	yes
IOG	Novel innovation	0	Domestic multinationals show a higher rate of innovation output measured by novel innovations.	no
IOG	Innovation output	0	Domestic multinationals, Anglo-Saxon-owned companies and European-owned companies have a higher income from new products per worker.	yes
PG	Productivity	4.3.2.3.4	As measured by labour productivity, Anglo-Saxon-owned companies are more productive than all the other companies.	yes
FG	Funding	4.3.2.3.5	Domestic multinationals enjoy a higher probability of receiving public funding, whereas the Nordic-owned and the European-owned companies have a lower probability of being funded.	yes

4.4 Appendix

In addition to the selection models discussed above, we consider a multi-step production model to control for innovation input and innovation output when testing for the productivity gap.

4.4.1 The model

The theoretical model we consider is a modified version of the standard Cobb-Douglas production function. The approach used can be simplified by the following relationship:

$$\log Y = \alpha + \beta \log \mathrm{X} + \gamma \log K + \varepsilon \,, \qquad (3)$$

where *Y* is productivity at the firm level, *X* is a vector of standard inputs, and *K* is knowledge capital capturing the transformation process from innovation input to innovation output, and α and ε respectively represent systematic and random fluctuations in productivity. Here the focus is on estimation of γ, the elasticity of productivity with respect to knowledge capital.

The empirical model in the study is a modified version of the production function model introduced by Pakes and Griliches (1984) and further developed by Crépon, Duguet and Mairesse (1998). The model, referred to as the CDM model, includes four equations and three established relationships including the innovation input linked to its determinants, the so-called knowledge production function relating innovation input to innovation output, and the productivity equation relating innovation output to productivity.

The basic econometric problems that the empirical model aims to solve are selectivity and simultaneity biases. When only R&D investing firms are considered, which is the most common case in innovation studies, a selection bias may arise. And when several links in the process of transforming innovation investment to productivity are considered in a simultaneous framework, one possible problem emerging is that some explanatory variables are often determined jointly with the dependent variable – i.e. they are not exogenously given and there will be simultaneity bias in the estimates.

The first two equations in our version of the CDM-model are estimated separately as a generalized tobit model, where observations on both innovative and non-innovative firms are included. The last two equations are estimated in a simultaneous equation system where the endogenous innovation output variable is limited to strictly positive values in the last step. More specifically, we have the following equations:

$$g^* = \beta_0^0 + \sum_n \beta_n^0 x_n^0 + \varepsilon^0 , \tag{4}$$

$$k = \beta_0^1 + \sum_m \beta_m^1 x_m^1 + \varepsilon^1 , \tag{5}$$

$$t = \beta_0^2 + \beta_k k + \beta_{MR} MR + \sum_l \beta_l^2 x_l^2 + \varepsilon^2 , \tag{6}$$

$$q = \beta_0^3 + \beta_t t + \sum_j \beta_j^3 x_j^3 + \varepsilon^3 , \tag{7}$$

where g^* is a latent innovation decision variable, k represents innovation input, t is innovation output, q is productivity, MR is the inverted Mill's ratio introduced to correct for possible selection bias, x^0, x^1, x^2 and x^3 are N, M, L and J vectors of variables explaining investment decision, innovation input, innovation output and productivity including employment, human capital and various innovation indicators variables. The coefficients β^0 and β^1 are vectors of unknown parameters to be estimated reflecting the impact of certain factors on the probability of being engaged in R&D and other innovation investments and on the actual level on these investments, the β^2 is parameters associated with the level of innovation output while β^3 is associated with the level of productivity.

The $\varepsilon^0, \varepsilon^1, \varepsilon^2$ and ε^3 are random error terms. We assume that the two error terms in the selection model are correlated and the two error terms in the simultaneous equation system are correlated. In addition, due to the predicted Mill's ratio and the predicted innovation input estimate in equation (6), both generated from the selection model, there is also a partial correlation between the error terms in the selection equation and the simultaneous equation. The two last equations can be estimated by two-stage least square or three-stage least square. In this report we are utilizing the 2SLS estimator.

4.4.2 Results

By and large, the results of the multi-step production model qualitatively support the findings of the analysis above (Tables 4-17 and 4-18). This rejects the innovation input gap hypothesis if the innovation input is measured by the likelihood to carry out innovation activities. Yet it supports the innovation input gap hypothesis if the innovation input is measured by the innovation expenditure per worker. As in the selection equations above, the domestic multinational companies and the Anglo-Saxon-owned multinationals stand out. The multi-step analysis also supports the innovation output gap as Anglo-Saxon-owned firms yield higher returns on innovation than domestic uni-national firms do. So do the domestic multinationals. We also find support for the productivity gap hypothesis as the Nordic-owned firms show higher labour productivity than the domestic uni-national firms do.

Table 4-17. Multi-step production function model.

Step 1: Selection equation Dependent variable: The probability to be an innovative firm			
	Coefficient		Std.err.
Foreign ownership	–0.067		0.120
Size	0.217	***	0.038
Local markets		Reference	
Regional markets	1.230	***	0.162
Global markets	0.867	***	0.139
Recently established	0.036		0.169
Recently merged	–0.096		0.141
Human capital	0.436	**	0.199
Investment per employee (log)	0.149	***	0.032
Constant	–1.967	***	0.233

Step 2: Innovation input equation Dependent variable Log innovation expenditures per employee			
D		Reference	
D-M	0.529	***	0.183
N-M	0.210		0.215
AS-M	0.447	*	0.238
EU-M	0.398		0.257
Size	–0.429	***	0.050
Local markets		Reference	
Regional markets	–0.157		0.281
Global markets	–0.126		0.248
Public funding for R&D	0.631	***	0.132
Process innovation	0.189		0.123
Continuous R&D	1.117	***	0.150
Constant	2.119	***	0.453

Note: *** (**,*) indicates significance at the 1% (5%, 10%) level. D= Domestic firms, non-multinational; D-M= domestic multinational; N-M= Nordic multinational, AS-M= Anglo-Saxon multinational; EU-M= European and other multinationals. 6 sector dummies included in the regression are not reported here.

Table 4-18. Multi-step production function model (continued).

Step 3: Innovation Output equation Dependent variable: The log of innovation sales per capita			
	Coefficient		Std. error
Predicted labour productivity	0.318		0.278
Predicted innovation input	0.23		0.175
D		Reference	
D-M	0.481	**	0.224
N-M	0.294		0.259
AS-M	0.545	*	0.294
EU-M	0.238		0.31
Size	–0.174		0.111
Inv. Mill's ratio from the sel. equn.	–1.113		0.742
Public funding for R&D	–0.414	*	0.23
Collaboration diversity	1.541	***	0.349
Human capital	–0.614	*	0.367
Constant	1.527		2.232

Step 4: Productivity equation Dependent variable: Log sales per employee per employee			
Predicted innovation output	0.185	**	0.087
Investment per employee (log)	0.271	***	0.038
D		Reference	
D-M	–0.068		0.111
N-M	0.184	*	0.101
AS-M	0.137		0.159
EU-M	0.117		0.159
Process innovation	–0.092		0.070
Size	–0.010		0.035
Human capital	0.641	***	0.147
Constant	4.290	***	0.190

Note: *** (**,*) indicates significance at the 1% (5%, 10%) level. D= Domestic firms, non-multinational; D-M= domestic multinational; N-M= Nordic multinational, AS-M= Anglo-Saxon multinational; EU-M= European and other multinationals. 6 sector dummies included in the regression are not reported here.

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5. Returns to innovation

Some of the results presented here are also discussed in Ebersberger and Lehtoranta (2003), and Ebersberger, Marsili, Reichstein and Salter (2004a, 2004b).

5.1 Introduction

It is a widespread empirical fact in studies of innovation that small numbers of actors or activities accumulate the greatest returns. For example, relatively few patents yield the highest income (Trajtenberg 1990), few firms are able to achieve radical innovations (Tushman and Anderson 1986), and a small number of scientific papers receive the greatest share of citations (Katz 1999). One reason for highly skewed outcomes is that the innovation process is highly uncertain, and the returns for success are as great as the punishment for failure is high. As Schumpeter (1942) indicated, the innovation process offers the carrot of spectacular reward or the stick of destitution. Despite the overall appearance of skewed distributions, there are relatively few empirical studies that examine the distribution of innovative returns among industrial firms.

Overall, we find that innovation returns are highly skewed in all industrial sectors. We also find that innovative returns are more highly concentrated in sectors with low levels of technological opportunities than in sectors characterised by high technological opportunities. In particular, we find that innovative returns in high-tech manufacturing and knowledge-intensive services are less skewed than in low-tech manufacturing and traditional service industries. This pattern is more or less invariant across countries as well as across the types of innovation.

5.2 Background

Innovation retains a central role in explanations of economic growth, industrial dynamics and international trade (Baumol 2002, Cohen 1995, Krugman 1995). Indeed, *The Economist* describes innovation as the "new religion" of OECD governments (The Economist 1998). Microeconomic studies of innovation appear to support this enthusiasm for innovation by governments. For example, it has been found that the firm-level innovation increases a firm's export potential (Bleaney and Wakelin 2002), profits over long periods and during recessions (Geroski et al. 1993), credit ratings (Czarnitzki & Kraft 2004), chances of surviving the market (Cefis & Marsili 2004), and market value (Hall 2000, Toivanen et al. 2002). This literature draws on a long tradition in economics of exploring how the ability to innovate can create Schumpeterian rents for innovators and how the ability of firms to capture these rents is shaped by the industrial and technological environment (Freeman 1994, Breschi et al. 2000, Cohen 1995).

In the investigation of returns for innovative effort, previous research has found that the returns for innovation are highly skewed. In fact, highly skewed distributions have been observed for a variety of indicators of innovative output: patent counts and citations (Trajtenberg 1990); profits from patented innovations (Scherer 1998, Scherer & Harhoff 2000); and published papers and citations of academic communities (Katz 1999). There are several possible explanations for the existence of these skewed distributions. There remains a high level of 'Knightian' uncertainty in the innovation process, indicating that many innovative efforts end in failure. It also appears that the ability to profit from innovative efforts is shaped by the nature of the technology opportunities and appropriability conditions within an industry (Freeman & Soete 1997, Klevorick et al. 1995). Innovations also differ significantly in their technological and economic importance. Some innovations are largely incremental in nature with modest performance implications leading to slight shifts in the market shares of incumbents within an industry. Other innovations can radically disrupt patterns of competition, creating opportunities for new entries and high levels of industrial turbulence (Utterback 1994). Research on the distribution of innovative returns seeks to better understand the sources and impact of such skewed distributions on policy, industrial and firm behaviour. This research asks: what is the share of proceeds that are gained by different actors for their innovative efforts? Is innovation a 'winner-takes-all' competition? Is innovation 'for the few, not the many'?

In exploring these questions and building on Schumpeter, researchers have attempted to understand different types of innovative activities and assess whether the distribution of innovation can be explained by a particular distribution. For instance, Scherer (1998) and Scherer, Harhoff and Kukies

(2000) compared the distribution of returns for different sets of innovation indicators, expressing different degrees of novelty. They found that, regardless of the indicators used, the returns to innovation were highly skewed and that a small minority of firms, patents and innovations account for the majority of the innovative returns. These variables were characterised by different behaviour at the tail from the rest of the distribution. While the overall shape of the distribution could be fitted with a lognormal distribution, the tail was better fitted by a Pareto distribution or power law. The Pareto distribution is a heavy or fat-tailed distribution – that is, the probability of having an extreme value at the tail of the distribution declines less rapidly than an exponential or lognormal distribution. In addition, the estimated value of the Pareto coefficient (the exponent of the power law) is generally lower than one. Within this range of the parameter, the mean and variance of the distribution are asymptotically infinite. This implies that even managing a large and diversified portfolio of innovative projects cannot reduce risk. Scherer and Harhoff (2000) show that this occurs in a wide range of cases, ranging from the licensing of patents by university research to the investment of venture capitalists in start-up companies. They remain sceptical about government policies that seek to 'pick the winners' and suggest a strategy of letting 'a thousand flowers bloom'.

Because the distribution of innovative returns appears to be Pareto only at the tail, Silverberg and Verspagen (2003) have estimated the cut-off point at which such behaviour appears. Using more sophisticated statistical methods based on extreme value statistics than earlier studies, they estimated the Pareto coefficient at the top tail of the distribution. They applied this method to patent citations and university patent royalties, including some of the datasets used by Scherer (1998) and by Trajtenberg (1990). Their results confirmed the extreme skewness of the distribution, as represented by Pareto-type tails, although with parameters in a more "stable" region than previously found, with the latter result holding for citations but not for returns.

As suggested by Scherer and Harhoff (2000), differences in the variability and stability between indicators of returns to innovation may reflect fundamental differences in the nature of the innovation. At present, only a few studies have assessed the implications of different types of innovation for distribution of innovative returns. This is a major limitation in the previous research and makes it difficult to generalise about the properties of the returns to innovation from these studies. Since Schumpeter (1942), a fundamental distinction between 'radical' and 'incremental' innovations has been made in the study of innovation. Radical innovations involve major changes in the character of new products and production processes (Freeman & Soete 1997). They are likely to generate a shift of the prevailing 'technological paradigm' and discontinuities in the 'technological trajectories' along which the process of incremental innovation takes place (Dosi 1982). In contrast, incremental innovations involve many small improvements in existing products or processes, which leads to increased product differentiation and/or better operating production processes (Freeman & Soete 1997). These innovations tend to occur more evenly over time and are more widespread across firms (Marsili & Salter 2004). Given these features of innovation, it can be expected that the degree of innovation can shape the distribution of returns to innovation.

A second limitation to the current literature on the distribution of innovation returns relates to inter-industry differences. The question is whether structural conditions specific to industries and technologies may contribute to lowering the variability of returns to innovation. In the current literature on the returns to the distribution of innovation, few studies have explored the distribution of innovative returns across different industries. In particular, no previous study of the distribution of innovative returns has explored the distribution of innovative returns in service industries. Given that service industries now account for close to 70% of Gross Domestic Product in many advanced economies, this is a severe limitation to the generalisability of the current literature.

In exploring inter-industry differences in patterns of innovation, Nelson and Winter (1982) argue that great uncertainty in the outcomes of innovative processes is expected to be associated with conditions of high technological opportunity typical of science-based sectors. In the literature on innovation there are a variety of competing definitions of technological opportunities. Klevorick et al. (1995) note that despite the popularity of the concept of technological opportunities there is no simple mechanism to measure the levels of opportunities across industries. In some models technological opportunities reflect the "distribution of returns to innovation, given demand conditions, the current level of technology and the appropriability regime" (Klevorick et al. 1995). Klevorick et al. use the analogy of drawing balls from an urn, where technological opportunities are the chances of drawing a ball with great rewards for a given level of investment. Technological opportunities are also seen to reflect the possibility that industries can draw from an expanding pool of scientific and technological knowledge, advances from other industries and the positive feedbacks between different technological advances within the industry over time (Klevorick et al. 1995). Building on this definition, Breschi, Orsenigo and Malerba (2000) define technological opportunities as “the likelihood of innovating for any given amount of money invested in research”. All of these definitions indicate that there are different levels of technological opportunities across industries, and these differences may shape the returns to innovative effort.

Although a focus on technological opportunities at the industry level can help explain inter-industry levels for a variety of economic variables of industrial behaviour, it says little about the performance variation found within an industry. In trying to explain variations in performance across firms within an industry, Dosi (1988) highlights three factors: *technological asymmetries*, *technological variety* and *behavioural diversity*. For Dosi, the diversity of innovative returns can originate from the *technological asymmetries* due to the uncertain and idiosyncratic nature of innovation. Diversity appears to be high in the high-technology sectors, and firms that are able to innovate may be able to capture substantial returns. Failure to innovate may put a firm at grave risk. In some high-technology sectors it appears that some innovators are able to gain from ‘increasing returns’ or ‘network effects’ (Shapiro and Varian 1998). These network effects may enhance the ability of innovators to capture higher returns than other firms over long periods, further skewing the distribution of returns.

However, an opposite mechanism can be envisaged that may moderate the diversity of innovative returns in high-technology sectors. Indeed, diversity of returns may also reveal the existence of *technological variety* in the technological trajectories explored by innovative firms – for example, in terms of specific production technologies and input combinations (Dosi 1988). Heterogeneity of returns may also originate from *behavioural diversity* across firms (Dosi 1988). As stressed by Pavitt (1998), new technological opportunities are likely to increase the ‘selective pressure’ on the innovative strategies of firms and their directions of research. This increased competitive pressure could mean that returns to innovation are quickly dissipated as competitors quickly launch rival products. Given the weakness of the competitive environment in the low-technology sectors, innovators may be able to sustain their Schumpeterian rents over a long period. Indeed, this position is supported by some empirical research on the profits from innovation (Geroski et al. 1993). Geroski et al. found that firms in low-technology industries had significantly higher levels of profits than non-innovators over time, and those firms who innovated also had much higher chances of survival during macroeconomic shocks, such as recessions.

Despite the results of the studies of profits from innovation, there has been little empirical evidence on the relationship between the distribution of innovative returns and the technological characteristics of different sectors. The empirical studies, such as Scherer and Harhoff (2000) that have looked at the skewness of the distribution by estimating the slope of the Pareto distribution, have mainly addressed this property at the aggregate level. Yet there are considerable differences in the organisation and structure of innovative firms across sectors and technologies (Pavitt 1984, Pavitt et al. 1987, Malerba & Orsenigo 1996). For example, Breschi et al. (2000) found that the properties of the knowledge base and learning processes in operation in a sector shape its patterns of innovative competition. They found that sectors characterised by high opportunities are likely to display a high degree of turbulence, entry and instability. Where appropriating technology is relatively easy, however, the industry is likely to be highly concentrated and with low numbers of innovators (Breschi et al. 2000). While such an approach contributes to a better understanding of the dynamic effects of knowledge on patterns of Schumpeterian competition, it says relatively little about the shape of the distribution of returns likely to be found in a particular industry.

Building on the previous literature, we seek to expand the treatment of the distribution of innovation returns in four areas. First, we investigate how the sectoral context shapes the distribution of returns to innovation. We begin by comparing the distribution of returns across a number of sectors with differing levels of technological opportunities for each country. Given the limited amount of research in this area, it is difficult to develop *a priori* statements about the impact of technological opportunities on the skewness of the distribution of innovative returns – i.e. whether high levels of technological opportunities will enhance the skewness of the distribution. Second, we investigate the distribution of innovative returns in services and compare these patterns with manufacturing. Unfortunately, there is no prior research or theory available that provides a prediction about whether the returns to innovation are more or less skewed in services or manufacturing. Third, we seek to extend the previous literature by exploring the distribution of returns for different types of innovation. Innovation theory suggests that novel innovation will be associated with more skewed distributions than incremental innovation. Last, we focus on the distribution of returns across countries to see if the patterns of the distribution of innovation returns may reflect some fundamental patterns that are invariant across countries.

5.3 Data

The data for the analysis is drawn from the third wave of the Finnish Community Innovation Survey covering the years 1998 to 2000.

To be able to compare the distribution of innovation returns, we create four industrial categories. In the case of manufacturing, we generate two classes of industries: low and high-technology manufacturing by merging high-technology manufacturing and medium-high-technology manufacturing into the same category. The low-technology manufacturing also includes the medium-low-technology manufacturing.[xxix] For services, we divide the firms into two groups: Knowledge-Intensive Services (KIS) and traditional services.[xxx] The KIS sectors cover a range of high-value service sectors, such as advertising, environmental consultancy, R&D services and business consultancy. Traditional services include all of the remaining service sectors.

5.4 Empirical results

In this section we explore the distribution of innovative sales for each country and for each industrial sector. Section 5.4.1 describes the sectoral and country differences in the propensity to innovate. We do not attempt to compare the innovation performance of the different countries. Instead, we focus on the underlying features of the distribution of innovative returns in each country. In the central part of the empirical analysis, Section 5.4.2 explores whether the differences in skewness between different industries in each country are significant.

5.4.1 Sectoral differences

Table 5-1 reports the descriptive statistics for each country and industrial sector.[xxxi] In general, and as expected, the share of firms that have engaged in innovative activities across all the firms that responded to the survey is higher in high-tech manufacturing than the other three sectors. However, there are considerable differences in the shares of innovators across countries. In the UK, a high number of firms have innovative activity in their firm in comparison with Finland and the Netherlands. Yet in Finland the percentage of firms who innovated among those with active innovative activity is much higher than in the UK. The pattern of innovators in the Netherlands lies between Finland and the UK. This pattern is also reflected at the industry level. Finnish low-tech manufacturers and traditional services have a much higher rate of innovation than UK firms in the same sector. Indeed, the rate of innovation among UK firms in these low-opportunities sectors is very low in comparison with Finland and the Netherlands.

Table 5-1. Descriptive statistics of sales from innovation.

	Low-Tech	High-Tech	Traditional	KIS
Data.Structure.(whole.sample)				
No of firms	677	369	300	271
% with innovative activity	48.89	66.4	36.67	53.14
Data.structure.(innovation.act.)				
No of firms	331	245	110	144
% of innovators	82.17	94.23	80.91	93.06
% of novel innovators	63.14	77.5	67.27	74.31
% of sale due to innovations				
Mean	0.15	0.27	0.17	0.24
Median	0.1	0.2	0.1	0.15
Standard.deviation	0.2	0.25	0.25	0.26
Coefficient.of.Variation	129.77	94.89	145.85	108.32
Skewness	2.15	1.33	2.05	1.58
Kurtosis	4.62	1.1	3.41	1.68
% of sale due to novel innovations				
Mean	0.1	0.18	0.12	0.16
Median	0.04	0.1	0.03	0.05
Standard.deviation	0.16	0.24	0.21	0.25
Coefficient	165.48	133.19	179.06	154.69
Skewness	2.84	1.86	2.84	2.23
Kurtosis	9.19	2.89	8.38	4.29

Table 5-1 also shows that the mean of the share of innovative sales differs across countries. Firms in the Netherlands and Finland have higher levels of innovation sales than firms in the UK. This pattern is consistent for both innovation and novel innovation. The differences between countries are even more pronounced when comparing the median of innovation sales. With regard to the returns from innovation, Finland and the Netherlands are remarkably alike in terms of mean and median. The UK, however, shows a different pattern with much lower returns from innovation. The similarity for the Finnish and the Dutch samples of innovative companies does not carry over to the returns to novel innovation. Here the Netherlands and the UK are quite similar. In comparison, Finnish firms have higher returns to novel innovations. As the data for all three countries is generated by identical questionnaires, the results are comparable and they indicate that there are considerable differences across countries in innovative behaviour (or at least in how firms understand measures of innovative behaviour in the CIS survey).

However, since our focus is on the distribution of innovation performance within countries rather than across countries, these differences are put to one side. It is interesting to note for the subsequent analysis that there are profound differences across the countries in the distribution of innovative returns.

Table 5-1 presents skewness measures for each industrial sector. We find that among the four sectors, low-tech manufacturing and traditional services have the most skewed innovative returns distributions. Indeed, this pattern is consistent across all three countries. A corresponding pattern emerges from the kurtosis measure, where low-tech manufacturing and traditional services exhibit a higher kurtosis (that is, fatter tails) than the other two sectors. The coefficient of variation also indicates that the returns to innovation are more dispersed away from the mean in the former than the latter sectors. This pattern may be partly due to the lower percentage of innovators in these industries and hence a higher number of respondents reporting a zero percentage of sales attributable to innovations or novel innovations. By excluding the observations that report a zero percentage of sales attributable to innovation and performing in the analysis of this sub-sample, we find that there appears to be no overall difference in the results.[xxxii] This finding indicates that differences across sectors in terms of technological opportunities may shape the distribution of innovation returns.

Since we are interested in whether the distributions are alike across different sectors, we apply a Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test is well suited to our purpose because it provides a measure of the distance between two distributions. Table 5-2 presents the comparisons between results throughout the four sectors for each country. Both the distance (D-statistics) and its associated p-value are reported for each possible sectoral combination. We analyse both the share of sales from innovation as well as the share of sales from novel innovation for all three countries.

Table 5-2. Kolmogorov-Smirnof test of differences in the distributions.

	D-value	Sig
% due to innovation		
Low-Tech vs. High-Tech	0.2824	***
Low-Tech vs. Trad. Serv.	0.0675	
Low-Tech vs. KIS	0.2069	***
High-Tech vs. Trad. Serv.	0.2922	***
High-Tech vs. KIS	0.1038	
Trad. Serv. vs. KIS	0.2261	***
% due to novel innovation		
Low-Tech vs. High-Tech	0.1842	***
Low-Tech vs. Trad. Serv.	0.0431	
Low-Tech vs. KIS	0.1545	*
High-Tech vs. Trad. Serv.	0.2048	***
High-Tech vs. KIS	0.0992	
Trad. Serv. vs. KIS	0.1293	

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

In the case of Finland, and KIS and high-technology manufacturing, the equality of the distributions cannot be rejected when considering KIS and high-technology manufacturing. This indicates significant differences in the spread of innovative returns. The distribution of low-technology manufacturing is also not significantly different from traditional services. These results hold for the returns on novel innovation. The equality of distributions between KIS and traditional service sectors cannot be rejected for innovation, but not for novel innovation. For the UK and the Netherlands, the equality of the distributions for all combinations of sectors and any measure of innovative return has to be rejected, indicating highly sector-specific patterns to the distribution of innovative returns. The only exception is the combination of low-technology manufacturing and KIS in the UK for the returns on novel innovations.

The results show that for Finland, the level of technological opportunity in a sector shapes the type of distribution of innovative returns. Indeed, the distribution of high-tech manufacturing and KIS were similar, as were low-tech manufacturing and traditional services. For the UK and the Netherlands, no overall pattern emerged. It appears that in these countries the distribution of innovative returns across sectors is fairly diverse. These findings indicate that country-specific properties do shape the distribution of returns and that levels of technological opportunities can only explain part of the distribution of innovative returns across sectors over different countries.

5.4.2 Significantly different skewness

To be able to test the equality of the skewness measures, we use a bootstrap methodology to resample and estimate the mean skewness in the sectors (Efron & Tibshirani 1993). Since there are no standard deviation measures of skewness, it is necessary to apply alternative ways of testing for significant differences in the skewness of the distributions. Our goal is to assess whether the patterns we found in the descriptive analysis can be supported by a more rigorous statistical analysis. In particular, we are interested in whether technological opportunities shape the distribution to innovative returns.

In Table 5-3, we report the estimations for the estimated difference for the means of the skewness and bounds of the 95% confidence intervals. This shows that the mean difference in mean skewness between innovations and novel innovation is negative and statistically significant in all sectors. As expected, we find that the returns from novel innovation are significantly more skewed than the returns from innovation.

Table 5-3. Differences in mean skewness.

	Left CL	Mean	Right CL
Innovation – novel innovation			
Low-Tech Manufacturing	–0.686	–0.682	–0.677
High-Tech Manufacturing	–0.545	–0.542	–0.538
Traditional Services	–0.777	–0.768	–0.76
Knowledge-Intensive Services	–0.672	–0.667	–0.662
Share of sales % due to innovation			
Low-Tech vs. High-Tech	0.8047	0.8079	0.8211
Low-Tech vs. Trad. Serv.	0.0606	0.0661	0.0716
Low-Tech vs. KIS	0.549	0.553	0.557
High-Tech vs. Trad. Serv.	–0.747	–0.742	–0.737
High-Tech vs. KIS	–0.259	–0.255	–0.251
Trad. Serv. vs. KIS	0.4812	0.4869	0.4926
Share of sales % due to novel innovation			
Low-Tech vs. High-Tech	0.9436	0.9481	0.9526
Low-Tech vs. Trad. Serv.	–0.028	–0.021	–0.013
Low-Tech vs. KIS	0.5621	0.5677	0.5734
High-Tech vs. Trad. Serv.	–0.976	–0.969	–0.962
High-Tech vs. KIS	–0.385	–0.38	–0.375
Trad. Serv. vs. KIS	0.5805	0.5883	0.5961

Note: Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1

Table 5-3 also reports the comparison of the skewness measures for all combinations of sectors. Overall, the sectoral values of all skewness measures are significantly different.

Ebersberger, Marsili, Reichtein and Salter (2004a) contains a comparative analysis between Finland, the Netherlands and the UK. Two major patterns emerge. First, industries with high levels of technological opportunities are accompanied by less skewness in the distribution of the innovative returns both in manufacturing as well as in services. There is one exception to this pattern. In the Netherlands, knowledge-intensive services are more skewed than low-tech manufacturing. However, in all three countries and for both types of innovations we observe the traditional services to have a more skewed distribution of innovative returns than knowledge-intensive services. We also find that, independent of the type of innovation, the distribution of innovative returns in the low-tech manufacturing is more skewed than in the high-technology manufacturing.

Second, we found some consistent patterns in the skewness of the distribution of innovative returns between manufacturing and services across countries. In Finland and the UK, where the levels of technological opportunity are high, we find that manufacturing is more skewed than services for novel innovation. In the Netherlands the pattern is reversed. For industries with low technological opportunities, and for novel innovation, we find that services are more skewed than manufacturing in all countries. For innovation and for industries with high opportunities, services appear to be less skewed than manufacturing in Finland and the UK. However, in industries with low opportunities the results are mixed. In Finland manufacturing is more skewed than services. In the Netherlands and the UK the pattern is reversed. When comparing the results across the two different forms of innovation, we find that there are only few cases where the patterns differ across countries, suggesting that there may be some consistency in the distributions of innovative returns in services and manufacturing across the countries. In sum, knowledge environments with relatively low levels of technological opportunity reveal higher levels of skewness in the distribution of innovative returns. This pattern is invariant across all three countries. In addition, independent of the knowledge environment, a higher degree of novelty of innovation is associated with higher skewness of returns. This pattern is fairly consistent over the three countries, although it is more pronounced in the UK and the Netherlands than in Finland. To a certain extent, the institutional environment seems to mediate the effect of uncertainty on the distribution of returns.

5.4.3 Conclusions

The returns to innovation are highly skewed across firms within an industry. In this respect, Schumpeter was right that innovation creates many winners and losers. In order to deepen previous aggregate studies of the distribution of innovative returns, we examined the shape of the distribution of innovative sales across four sectors for two types of innovation within three countries. Our goal was to examine the role of technological opportunities in shaping the returns to innovation. We found that the distribution of rewards in a particular sector is profoundly shaped by the nature of the technological opportunities; innovators can reap great rewards in sectors with high levels of technological opportunities. These sectors accounted for a considerable percentage of all innovative activity within each of the three countries. In sectors with low technological opportunities, as expected, there are fewer innovators.

Although there are fewer innovators in sectors with low technological opportunities, the distribution of innovative sales in these sectors are more highly skewed than in sectors with higher levels of technological opportunities. For all three countries, traditional services is the most skewed industry in terms of the distribution of innovative returns. Low-tech manufacturing is also highly skewed in comparison with high-tech manufacturing and knowledge-intensive services in all three countries, except for the knowledge-intensive services in the Netherlands. Overall, the results suggest that the rewards for innovating are greater in sectors with low technological opportunities than in high-technology sectors. Indeed, in these sectors, fortune does favour the brave.

This finding is consistent with the Geroski et al. (1993) study of innovation and profits. They found that benefits of innovation to firm-level profits were greatest in the low-technology sectors, especially during recessions. Our findings and Geroski et al's could be explained by the nature of the competition in the low and high-technology sectors. In the high-technology sectors competitors may be able to easily imitate the products of an innovator. For example, innovations, such as Apple's Ipod, are often quickly surrounded by competing products. The high-technology sectors are also characterised by high levels of entry and exit and extreme market volatility. They are considered to be associated with the early stages of the Industry Life Cycle (Klepper, 1997). In contrast, competitors in the low-technology sectors may lack the ability to imitate the products of innovators. Here innovative firms may be able to establish a strong position in the market. The combination of a weak 'selection environment' and low levels of overall technological opportunity in these sectors may deter innovative effort.

Theoretical explanations of the role of opportunities in shaping the distribution of returns remain relatively poorly developed. Previous studies have attempted to fit the distribution of returns to a function to see whether the distribution is Pareto or log normal. These studies are extremely beneficial, but say little about the sectoral environment that may give rise to these patterns of returns. Focusing on the sectoral level, Nelson and Winter (1982) suggested that high-opportunity environments are characterised by rich rewards for innovators. At the same time, Pavitt argued that the selection mechanism in high-opportunity environments is extremely strong and that many firms in these sectors have similar technological profiles. Given these two perspectives, it was difficult to develop *a priori* expectations about the distribution of innovation returns across sectors. We found that the balance of evidence indicates that Pavitt was correct in highlighting the selective pressure of high-technological-opportunity environments in shaping the returns to innovation.

There are several policy implications arising from the research. The first relates to the use of CIS data to compare national innovation performance. Within the OECD, Community Innovation Surveys are increasingly being used in policy debates to assess the innovative performance of different countries (OECD, 1999). For example, in the UK, recent government innovation strategy documents have suggested that the UK needs to move up the 'league table' of innovators. Our study shows the difficulty of direct country-country comparisons in innovative performance using the CIS. We found substantial differences across countries in the shape of innovative returns. Given the results, it could be argued that there is a substantial performance gap between UK and Finnish firms. However, given other economic evidence, it is difficult to believe such great differences in performance actually exist. This suggests that the use of Community Innovation Surveys for cross-country benchmarking requires a degree of caution and that such analyses should be combined with other measures of economic and innovative performance. Second, the fact that the distribution of innovative returns are more highly skewed in the low-technology sectors indicates that government efforts to promote innovative efforts in these sectors may yield greater returns than investments in the high-technology sectors, where the competitive pressure within the market may be a sufficient stimulus to innovation. In the low-technology sectors innovators can reap greater rewards and, therefore, greater policy attention could be directed at creating more low-technology innovators. In these low-technology environments there may be a lack of competitive stimulus for firms to make investments in innovation.

The difficulty with research on the distribution of innovative returns is that the data appears to be more advanced than the theory. Greater research is required on the distribution of returns to establish a new set of 'stylised facts' about the returns to innovation. Indeed, there is considerable potential to link these studies of innovative returns to theories of firm growth and explore how the shape of the distribution of innovative returns affects the industrial organisation of an industry. New research could explore which factors shape the distribution of innovative returns across different industrial sectors. Efforts to link the skewness of innovative returns to market concentration, appropriability regimes and industry turbulence would be particularly useful. With new and more powerful datasets on innovation, the rewards for theoretical developments and models that explain differences in the distribution of innovative returns could be substantial.

5.5 Determinants of the returns to innovation

Having discussed the distribution of the returns to innovation above, we have to investigate the factors that determine the returns to innovation. The first, most prominent one is the research and development effort companies spend for innovation.

Since the seminal work of Schumpeter (1942), the relationship between research and development (R&D) and firm performance has been a subject of considerable economic analysis. Although R&D is generally acknowledged as one of the key drivers of innovation and firm performance (Kleinknecht & Mohen 2002), it has been difficult for researchers to find a direct relationship between R&D activity and firm performance (Klomp & Van Leeuwen 2001). The reason for these difficulties is that firms have specific capabilities that complement their R&D activities that are difficult to measure. In addition, firms may organize their innovative effort in different ways (e.g. in the composition of R&D) and thus gain different returns from their investment (Cohen 1995). Overall, however, there is little doubt that there is a correlation between R&D and the firm-level innovation performance (see e.g. Cohen 1995, Mairesse & Mohnen 2002). The relationship between R&D and economic performance strictly defined is also heavily substantiated (see e.g. Branch 1974, Grabowski & Mueller 1978, Ravenscraft & Scherer 1982, Holak et al. 1991).

Previous attempts to link R&D to firm performance have mostly relied on the number of patents or patents citations as proxy for firm performance measuring both innovative and economic performance. The problems with patents and patent citations as an indicator of innovation output are well established – not all patents become innovations, the importance of patents varies across industries, and few service firms patent (Griliches 1990). Innovation survey data provide a complementary approach to assess the link between firm performance and R&D, which can help to overcome some of the problems associated with patent analysis. In this study we use a measure of performance that combines both innovative and economic performance by drawing on firm-based estimates of the share of sales that come from innovation. By doing so, we hope to capture the combined effect of innovative activity in one measure and contribute significantly to the discussions on the economic benefits of R&D. This new indicator has been used to measure the production of innovation in firms and countries, and to identify its determinants and the effects on economic performance (Mairesse & Mohen 2002, Czarnitzki & Kraft 2004). In particular, this approach has been applied within broad structural models (Crépon et al. 1998) that extend earlier work on the link between R&D and productivity (Griliches 1994).

The goal of this paper is to re-interpret the relationship between R&D and firm performance using a quantile regression approach. This method allows us to explore whether sales from innovation are altered by R&D in different ways, depending on which part of the innovation sales distribution we look at. In doing so, we seek to move the study of R&D and innovation away from mean-centered OLS regressions. Adopting a quantile approach allows researchers to gain a fuller and more complete picture of one of the key relationships that underlies economic growth.

5.5.1 Methodology and estimation

Our approach is based on the linear quantile regression introduced by Koenker and Bassett (1978). The use of quantile regression has two major advantages. First, it reveals differences in the relationship between the endogenous and the exogenous variables at different points of the conditional distribution of the dependent variable. Second, the coefficient estimates of the quantile regression are more robust than the results of least square regression, where the mean value of the dependent variable is predicted. This is especially true in the presence of outliers, as well as for distributions of error terms that deviate from normality (see Buchinsky 1998, Koenker & Hallock 2001).

The τ th quantile is defined as $Q(\tau) = \inf\{y : F(y) \geq \tau\}$, where $0 < \tau < 1$ and Y is a random variable, which is distributed with $F(y) = P(Y \leq y)$. Consider the linear regression model $y_i = \overline{x_i}\overline{\beta} + u_i$ for $i = 1...n$ where $\overline{x_i}$ and $\overline{\beta}$ are k the vectors of explanatory variables and their estimated coefficients respectively. y_i and u_i are the dependent variable and the iid distributed error term, respectively. The OLS estimator is found by minimizing the sum of the squared residuals $\sum_{i=1}^{n}(y_i - \overline{x_i}\overline{\beta})^2$. On the other hand, the quantile regression estimator is the vector β that minimizes:

$$\min_{\beta \in \mathrm{R}^k} \left[\sum_{i \in \{i : y_i \geq \overline{x_i}\overline{\beta}\}} \tau \left| y_i - \overline{x_i}\overline{\beta} \right| + \sum_{i \in \{i : y_i < \overline{x_i}\overline{\beta}\}} (1-\tau) \left| y_i - \overline{x_i}\overline{\beta} \right| \right] \tag{1}$$

Generally, the objective function (1) represents an asymmetric linear loss function. For $\tau = 0.5$, however, it becomes the absolute loss function determining the median regression. In this case it is symmetric. Varying the parameter τ in the interval between 0 and 1 generates all the regression quantiles, revealing the conditional distribution of y given $\overline{x}$. The parameter estimate for the *j*-th exogenous variable is interpreted as the marginal change in the dependent variable due to a marginal change in the *j*-th exogenous variable conditional on being on the τ -th quantile of the distribution.

5.5.2 Data

The data used is a sub-sample of the third Community Innovation Survey carried out by Statistics Finland. To remedy potential endogeneity problems in the CIS dataset, we do not use the R&D effort in the innovation survey that relates to the year 2000. We extract the R&D expenditures for the year 1998 from Statistics Finland's R&D survey for each firm. Our dataset contains data on 760 companies where the R&D input is available. Hence, by definition, we exclude recently established companies. The data covers companies from both the manufacturing sectors as well as from the service sectors. The variables used in the analysis are summarized in Table 5-4. We introduce a number of control variables to account for industrial concentration and appropriability. Additionally, it should be mentioned that the innovation sales distribution is very skewed (skewness = 1.747), arguing for a quantile approach rather than a least squared.

Table 5-4. Descriptive statistics.

Description	Var	Mean	St.dev
Innovative sales; Sales of new products relative to total sales	innosale	0.236	0.241
R&D expenditure as share of sales	rdx	0.071	0.144
R&D expenditure as share of sales, squared	rdx2	0.026	0.119
Employment (log)	empl	4.388	1.520
Concentration ratio (CR 10) in 2 digit industries	cr10	0.425	0.219
Appropriability condition in 3-digit industries	apc	1.152	0.341
High-technology manufacturing	seht	0.316	0.434
Low-technology manufacturing	selt	0.378	0.485
Knowledge-intensive services	sekis	0.187	0.390
Other services	seos	0.117	0.322

Note: The term 'new products' also includes new services in the context of firms in the service sectors. The sectoral classification dummies seht – seos are defined on the basis of the classification in OECD (2001), Here, medium-high (low)-tech manufacturing industries are classified as high (low)-tech manufacturing. The concentration ratio is retrieved from Statistics Finland (2002). The appropriability conditions are constructed in the vein of Belderbos et al. (2003).

5.5.3 Results

Table 5-5 shows the result of the OLS regression on the mean as well as the results of the quantile regression for selected quantiles. Table 5-6 contains a graphical representation of the results. The regressions were performed on the level of quantiles/percentiles. But Table 5-5 only reports the results of the deciles ranging from 20 to 80.

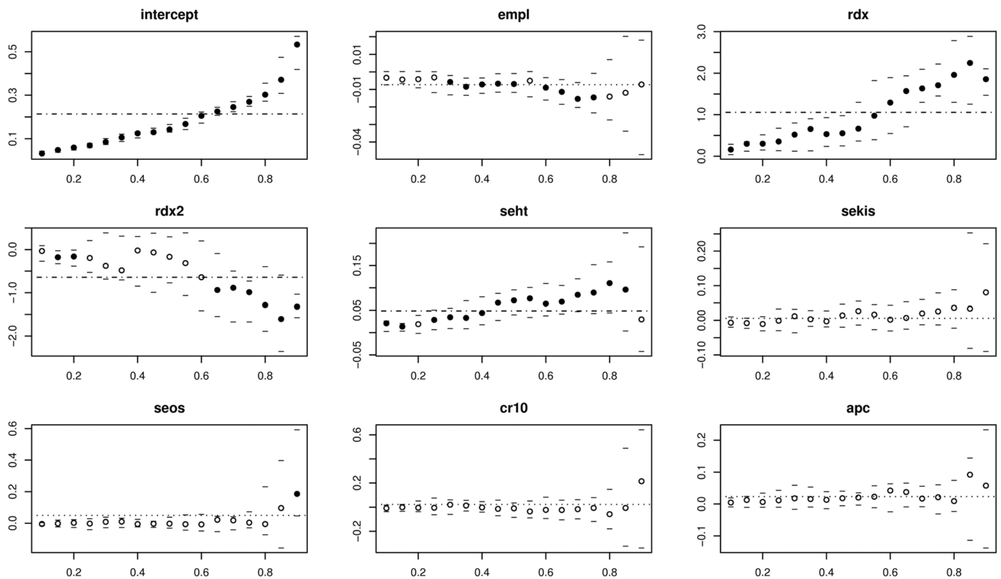
The estimate of the intercept can be interpreted as the share of innovative sales of a firm in the low-tech sector with a size of approximately 80 employees, an R&D intensity of 8.3%, operating in a sector with a concentration ratio (CR10) of 43.3% and average appropriability in the sector. Even in the 30% quantile, these companies earn about 2.6% of their turnover from innovation. This share increases to 27.7% in the 80% quantile.

Table 5-5. Results of the OLS and the quantile regression.

		Quantiles								
	Mean	10.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	90.0%
(Intercept)	0.534***	0.031***	0.059***	0.084***	0.124***	0.142***	0.205***	0.245***	0.303***	0.534***
rdx	1.856***	0.160*	0.301***	0.520***	0.532***	0.664***	1.292***	1.633***	1.959***	1.856***
rdx2	–*** 1.324	–0.035	–0.162 *	–0.379	–0.022	–0.169	–0.644	–0.888*	–1.284 *	–1.324**
empl	– 0.007	–0.003	–0.004	–0.006**	–0.007**	–0.007**	–0.009**	–0.015**	–0.014	–0.007
cr10	0.215	–0.009	–0.005	0.020	–0.002	–0.010	–0.023	–0.017	–0.058	0.215
apc	0.058	0.005	0.006	0.018	0.013	0.020	0.042*	0.017	0.009	0.058
seht	0.030	0.021*	0.019	0.035***	0.044***	0.072***	0.065***	0.084***	0.111***	0.030
sekis	0.080	–0.007	–0.011	0.012	–0.003	0.027	0.002	0.020	0.036	0.080
seos	0.186	–0.005	0.002	0.009	–0.006	–0.003	–0.008	0.018	–0.006	0.186**

Note: The significance of the parameter estimate in the OLS regression is computed using heteroskedasticity robust estimations of the standard errors. Following the recommendations in Long and Ervin (2000) we use the HC3 suggested in MacKinnon and White (1985). Computation of the significance of the parameter estimate in the quantile regressions used the rank score method used in Koenker (1994), which is highly robust for many forms of heteroskedastisticity (Kocherginsky, He & Mu 2004).

Table 5-6. Coefficient estimates of OLS and quantile regression.



Note: The vertical axis represents the estimated parameter for each exogenous variable whereas the horizontal axis displays the quantile. The horizontal line represents the parameter estimate of the OLS regression. A dash-dotted line indicates that the parameter estimate is significantly different from zero. A dotted line indicates no significance. The estimate parameters in the quantile regression are displayed as dots and circles. A filled dot indicates a parameter estimate significantly different from zero whereas a circle indicates no significance. The 10% confidence interval of the parameter estimates based on the Koenker (1994) rank inversion methodology is indicated by (-).

For the R&D intensity, the OLS results imply an inverted U-shaped or curvilinear influence on innovative performance. However, the quantile regression delivers a much richer picture of the data. In the quantiles below 45% we find little significant influence of R&D on the innovation sales. Between the 45% quantile and the 70% quantile we find a significantly positive and linear relationship between R&D expenditure and the innovation sales. Starting from the 70% quantile the linear relationship turns into an inverted U-shaped relationship. This finding indicates that there are diminishing rates of return on investments in R&D for higher levels of performance. In other words, the relationship turns from constant returns to decreasing returns in the higher quantiles.

The parameter estimate of the least square regression tells us that firm size is negatively correlated to sales from innovation. But again, the quantile regressions tell a different story. Regressing against the quantiles between the 10% and the 50% quantile does not produce a negative significant parameter estimate. Between the 50% quantile and the 80% quantile the size of the company has a significantly negative influence on the innovation sales. Although the coefficient estimate is still negative above the 80% quantile, it is not significantly so.

With reference to the sector variables, only the high-tech manufacturing sector shows significant positive parameter estimates in the quantile regressions, even though the traditional least square regression method does not. This suggests that high-tech manufacturing firms reap significantly higher sales from their innovations than low-tech manufacturing firms. High-tech manufacturing firms' share of sales from innovations increases by 3.0 percentage points in the 20% quantile to 9.5 percentage points in the 80th quantile of the innovative sales. However, this increasing pattern of performance is not persistent. From the 50th to the 60th quantile there is a small decrease in the parameter estimate. However, the difference is not significant, indicating that the difference between the low-tech and high-tech increases as we move up on the distribution function. The parameter estimates for the knowledge-intensive service industries present a more mixed picture. In the lower quantiles, up to the 30% quantile, knowledge-intensive service firms enjoy significantly higher returns from innovation than the low-technology manufacturing.

The industry levels of concentration appear to have little explanatory power in the share of sales from innovation across all of the quantiles. The appropriability conditions do play a role in determining the returns from innovation in the analysis from just below the 40% percentile to just above the 75% percentile. The stronger the efforts of the companies in the sector to protect their innovations and inventions, the higher their innovative returns will be. In the low quantiles and the high quantiles the appropriability conditions in the sector do not affect the returns from innovation.

5.5.4 Implications

In order to re-interpret the relationship between R&D and innovation, we used quantile regression and the database of Finnish innovative firms. Our study shows that OLS estimates are potentially misleading because they fail to capture how R&D expenditures shape economic gains from innovative activity when focusing on the entire economic gain distribution. The quantile approach shows that R&D especially matters in the medium quantiles of the innovative gains distributions. In the upper quantile R&D expenditure is subject to decreasing returns. Using the quantile regression approach yields new insights and suggests a wide range of future research possibilities for gaining a better relationship between investments in innovation and firm performance.

6. Summative conclusions and directions for future work

This study summarized the research on the innovation activities of Finnish firms and its many facets. We set out to analyze the impact of public funding, the pattern of collaboration for R&D and their determinants, the impact of foreign ownership on innovation activities and firm performance, and, finally, the returns from innovation, their determinants and distributions.

Besides the results relating to the research questions, the analysis reveals several insights about the data sources available. First and foremost, we find that the data available in Statistics Finland's various registers, which can be supplemented by various surveys, is of astonishing quality and coverage and thus highly appropriate for the analysis of innovation activities. The feature that various registers and surveys can be merged based on unique firm or employee identification numbers enables the researcher to draw on a rich and comprehensive data source without carrying out a single survey. A multitude of research questions can be tackled in a cost-efficient way, as cost-intensive surveys and data collection is not required. Although having a plethora of reliable data sources at hand, not all research can be covered by the register and survey data available. This is even more the case when the object under investigation is not a sector, a firm or an establishment. New types of data, such as project-level data, may also benefit from the availability of Statistics Finland's rich data sources, as the research in Lehtoranta (2005) shows. The research in Section 3.1 and Section 3.2 here also shows that project-level data supplements firm-level data. Hence any effort to make sure that new types of data can be combined with the available data sources seems worthwhile as both the new and the already existing data sources mutually benefit.

Second, some of the data sources, such as Statistics Finland's registers, are consistent over time. Quite sadly though, the most relevant data source for the empirical research of innovation activities – the Community Innovation Survey – contains data which, in all its dimension, is not comparable over time. This is a severe limitation for conducting intertemporal comparisons. However, Section 3.2 shows that intertemporal comparisons are possible, albeit at the cost of a reduced set of available variables.

Impacts of public R&D funding

Our analysis of the impacts of public R&D funding shows the positive influence public support has on the innovation output and the innovation outcome of companies. Innovation output is measured by the companies' likelihood to patent and innovation outcome is measured by the companies' labour demand and the companies likelihood to retains its independence. We are able to show that a company receiving subsidies is more likely to apply for a patent than it would have otherwise. We are also able to support the hypothesis that, in the medium-run, publicly funded firms show a more favourable employment growth. Furthermore, our investigation into the effect funding has on the vanishing of companies reveals that although public R&D funding is a subsidy, it has almost no distorting effect on the survival of companies; rather, it supports their independence.

We see several avenues for future research. First, the innovation output indicator used here can be extended and complemented. As we only investigated the likelihood to patent, a subsequent step would be to investigate the effect on the extent of patenting measured by the number of patents. A further step would be to use patent values to control for differences in the significance of patents. Second, patents as innovation output indicators can be supplemented with all the information contained in the patent application. Subsequently, the effect of public funding on the direction of companies' research strategies could be investigated. Third, our analysis here used a public funding dummy, which indicated that companies have received public R&D funding for collaborative R&D. Hence we measured the simultaneous effect of collaboration and public R&D funding. These effects will be disentangled in later research.

Determinants of collaboration

As already indicated above, the analysis presented in Section 3 focused on the collaborative arrangements of Finnish companies. It presents an analysis of the collaboration of companies with providers of knowledge-intensive services and an analysis of the determinants of collaboration with various partners during the 1990s.

The analysis of the determinants of collaboration for innovation shows that for both horizontal and vertical collaboration we can tell the story about building up absorptive capacities as the probability is positively influenced by the diversity in R&D activities. Second, the probability of the collaboration of the service sector firms increases over time. Third, the hypothesis that high-medium-technology manufacturing firms and high-technology firms have a higher propensity to collaborate is not supported by the results here. Fourth, the vertical collaboration propensity of firms belonging to a corporate group of firms decreases between 1996 and 2000. Fifth, vertical co-operation is strongly influenced by experienced bottlenecks in the knowledge domain; non-vertical collaborations seem not to be greatly influenced by the gaps in the knowledge domain. Sixth, in both vertical and non-vertical collaboration the relevance of economic hampering factors on the collaboration is a quite recent phenomenon. Finally, it seems that for managing a certain degree of complexity, vertical collaboration may not be appropriate as the high-technology manufacturing dummy does not have any significant parameter estimates.

Analyzing the collaboration with providers of knowledge-intensive services illustrates that in traditional industries the knowledge-intensive services are frequently used and appreciated. The most appreciated provider of knowledge-intensive services seems to be the governmental research institutes. This analysis, however, neither quantifies nor qualifies the role of knowledge-intensive services in the generation of innovations. Further research is required to gain a detailed picture of the impact of knowledge-intensive services on the companies' innovativeness. Given that data for the analysis suggested here is not yet available, the first step would be to approach the question by collecting case evidence.

The analysis of the collaboration for innovation above only analyses a dummy variable. Hence it can only shed some light on the determinants of the likelihood of certain types of collaboration. The issues about the size of the collaboration, its intensity and the composition and structure of the network remain untouched. Future research would require additional data on the structure and the composition of the networks and their persistence. As mentioned above, when discussing the impact of public funding, future research should also investigate the impact of public funding on the network formation and its sustainability. Future research will have to tie together the discussions of Section 2 and Section

3. To our knowledge, the data required for those types of analysis does not yet exist in the Finnish context.

Ownership and innovation activities

In the analysis of Section 4 we first extended the current discussion about gaps between domestic-owned and foreign-owned firms into a more detailed picture of the innovation and technology gaps. Mainly theoretical considerations led us to differentiate innovation input gaps, innovation output gaps, local embeddedness gaps, productivity gaps and funding gaps.

The empirical analysis utilizes the Finnish Community Innovation Survey covering the years 1998 to 2000. The analysis of the gap hypothesis starts with an exploratory analysis of the data, where we already find slight indications pointing to the differential behavior of foreign-owned and domestic-owned firms. The econometric analysis mainly consists of sample selection models that take the companies' decision whether or not to engage in innovation activities into account. As the previous literature does not offer a consistent picture of innovation and technology gaps, this paper is clearly in line with the current empirical literature. The picture we are drawing in this study is not undivided. Depending on the type of indicator we use for innovation input, innovation output and the local embeddedness, we find support for the gap hypothesis. By and large, we would support the innovation input gap hypothesis, the innovation output gap hypothesis, the local embeddedness gap hypothesis, the productivity gap hypothesis and the funding gap hypothesis. The gap hypotheses are not unanimous among the country groups of ownership. The Nordic-owned companies seem to be the most similar to the domestic-owned mononationals, although they do reveal a stronger embedding in the local environment and a stronger preference for patenting. European-owned companies exhibit higher innovation input and innovation output, achieved by a significantly lower propensity to receive public funding. The Anglo-Saxon-owned companies also reveal a higher innovation input, which they translate into increased innovation output. Whether or not Anglo-Saxon companies are found to be able to translate the higher innovation output into higher labour productivity depends on the econometric methodology used. The most appropriate modelling shows that Anglo-Saxon companies do not translate the higher innovation input into better productivity. Although we found some influence of ownership on the firms' innovation activities, the most robust result of the analysis is that the market strategy of the companies, such as a focused market, is a stronger determinant for the level of innovation activities than the ownership is.

This research utilizes innovation survey data and utilizes its broad set of indicators of innovation activities. Although the innovation survey data is the best data set available for this type of analysis, this section makes obvious the shortcomings inherent in the data set. First, as the data is cross-section, it does not allow for before-after analysis at the time of the switch of ownership. Second, the data source is excellent for depicting innovation activities; however, the innovation surveys contain little information on the other activities and characteristics of the firm. For the analysis of production activities and their efficiency in terms of productivity, an approximation of the accumulated capital stock is missing. And the ownership is captured in a rather crude fashion, which does not allow a differentiation between partially foreign-owned and fully foreign or domestic-owned firms. Improvements in this regard would be highly welcome. As the domestic multinationals are so distinctively different from the domestic-owned and foreign-owned firms, future research could concentrate on the role of domestic multinationals on the home economy and its innovation performance.

Returns on innovation

The returns on innovation are highly skewed across firms within an industry. In this respect, Schumpeter was correct in that innovation creates many winners and losers. In order to deepen previous aggregate studies of the distribution of innovative returns, we examined the shape of the distribution of innovative sales across four sectors for two types of innovation within three countries. Our goal was to examine the role of technological opportunities in shaping the returns on innovation. We found that the distribution of rewards in a particular sector is profoundly shaped by the nature of the technological opportunities. Innovators can reap great rewards in sectors with high levels of technological opportunities. These sectors accounted for a considerable percentage of all innovative activity within each of the three countries. In sectors with low technological opportunities, there are fewer innovators, as expected. The difficulty with research on the distribution of innovative returns is that the data appears to be more advanced than the theory. Greater research on the distribution of returns is required to establish a new set of 'stylised facts' about the returns on innovation. Indeed, there is considerable potential in linking these studies of innovative returns to theories of firm growth and explore how the shape of the distribution of innovative returns affects the industrial organisation of an industry. New research could explore which factors shape the distribution of innovative returns across different industrial sectors. Efforts to link the skewness of innovative returns to market concentration, appropriability regimes and industry turbulence would be particularly useful. With new and more powerful datasets on innovation, the rewards for theoretical developments and models that explain differences in the distribution of innovative returns could be substantial.

In order to re-interpret the relationship between R&D and innovation, we used quantile regression and the database of Finnish innovative firms. Our study shows that OLS estimates are potentially misleading because they fail to capture how R&D expenditures shape economic gains from innovative activity when focusing on the entire economic gain distribution. The quantile approach shows that R&D especially matters in the medium quantiles of the innovative gains distributions; R&D expenditure is subject to decreasing returns in the upper quantile. Using the quantile regression approach yields new insights and suggests a wide range of future research possibilities for gaining a better relationship between investments in innovation and firm performance. One avenue future research could follow is to leave the firm level and investigate on the level of innovation projects how R&D efforts lead to different types of innovation and how these types are related to the different economic returns.

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Notes

i We use innovation active and innovative as synonyms to describe that firms are carrying out innovation activities.

ii A large part of the analysis in this project will be inspired by evolutionary economics. Concerning the notion of the innovation process, evolutionary economics abandons the simple linear sequential model of innovation, which suggests that a somehow exogenous inventive stage is followed by an innovative stage. In the linear model of innovation it is hypothized that the technological opportunities are known by the firms, i.e. firms can act on a given and known set of new technological opportunities. The subsequent and final step in the linear model is the diffusion step. In the final step the successful innovations will spread over the whole economy. This model of the innovation process is hardly an adequate description of an innovation process taking place in knowledge-based economies (Kline 1985).

Although economic forces and motives have inevitably played a major role in shaping the direction of scientific progress, they have not acted within a vacuum but within the changing limits and constraints of a body of scientific knowledge growing at uneven rates among its component subdisciplines (Rosenberg 1976, p. 270). At first glance this implies that technology has its own rules and that the development of the technology is somehow guided by a predetermined path. When the internal relationships of technology are considered they turn out to be cumulative and driven by internal complementarities. Hence future technological steps hinge on past developments of the technology and tend not to be reversible. However, this does not mean that technology is completely independent of the economic system and the economic system is shaped by the technological development by a so-called science push approach – as discussed in Tisdell (1995). This approach again shows a linear flow from the scientific source to the market outcome. But it does not imply the opposite either. The technology is not solely and linearly shaped by the economic system as suggested by the induced bias (Hicks 1932), the demand pull (Schmookler 1966) or the scarcity push hypothesis (Habakkuk 1962). Moreover, technology has to be attributed an interactive nature that links the economic and the technological sphere. This very characteristic is most accessible when using the terminology introduced in Dosi (1982): first technological paradigm and second technological trajectory.

Technological paradigm means the state-of-the-art of the current technology, including all the technological problems and tools. It is the result of a selection process shaped by technological opportunities, defined by science and technology, and by institutional and market forces. Technological trajectories denote irreversible and cumulative processes within a technological paradigm, mainly consisting of incremental innovations. A shift in the paradigm, however, is caused by radical innovations. Within a technological trajectory, market forces also have a dominant role in shaping the actual technological situation. So it is not a linear relationship linking science and technology with markets. Markets and science simultaneously influence the technological change and innovations. On the one hand, market demand can only be met if the scientific and technical problems associated with the desired product or services can be handled. On the other hand, technological solutions that do not relate to any or a large enough market demand will not have an impact (Kline & Rosenberg 1986). If, on the basis of the discussion above, the linear structure of the innovation process is rejected, how else do we perceive the innovation process?

Focusing on this critique, a sequence of models of the innovation process is developed: the chain-linked model of the innovation process (Kline & Rosenberg 1986), the integrated theory and a systems integration and networking theory. In the latter one the innovation process has to be regarded as a joint process involving several actors. Innovations are generated as a result of collective action, hence the outcome of the process can be characterized as collective innovation (Allen 1983). The collective notion of the innovation process most strongly contradicts the ideas of the linear model. Here different actors, pertaining to different or even the same stages of the innovation process, may directly collaborate or indirectly influence each other. Various positive effects might be caused by collaboration such as a so-called cross-fertilization, knowledge sharing, cost sharing (Mokyr 1990, Pyka 1999). It has to be emphasized that the mutual influences are not of a one-way type; rather, they are back and forth, creating feedback loops. The central role in the whole introduction of new products and services can still be attributed to firms. Having abandoned the linear model of innovation, we have to offer some theoretical background that adequately reflects the innovation process sketched here. The theoretical framework will be discussed in the following section. Although this discussion relates directly to the notion of the innovation process discussed above, the relevance of the theoretical discussion might not be obvious at first glance. But it is relevant as the discussion of the theoretical framework might facilitate the discussion of the research questions, and the way to approach them empirically. The theoretical framework also influences data selection and the empirical methodology used (cf. Ebersberger 2002).

iii The discussion here does not include spillover effects that may occur for units other than the subsidized ones.

iv In the following discussion we use the term ’program’ as a synonym for any subsidizing activity carried out by Tekes. Hence any firm receiving subsidies for R&D activities participates in a program. *Program* here does not relate to the Tekes-internal notion of programs that summarize any activity to promote development in specific sectors of technology or industry. We use the terms ’program participation’ and ’receiving of subsidies’ as synonyms.

v As most chapters are selfcontained studies, at the beginning of each chapter we start numbering the equations with (1).

vi As the data only indicated the starting year and the termination year of the project we count both years as full years.

vii In some literature knowledge-intensive business services and knowledge-intensive service activities are used synonymously.

viii The boundaries of the system are commonly defined with reference to spatial and political terms: national systems of innovation (Freeman 1987, Lundvall 1992, Nelson 1993) regional/local systems of innovation (Castells & Hall 1993, Saxenian 1996, Cooke et al. 1997).

ix Pentikäinen (2000), Salo et al. (2004) and www.woodwisdom.fi demonstrate the pervasiveness of the Finnish Forest Cluster program. Salo et al. (2004) discuss an ex-ante evaluation, whereas Pentikäinen (2000) discusses an ex-post or interim evaluation of the program.

x The questions in the CIS 3 refer to the three-year period 1998 to 2000.

xi Innovation co-operation is defined in the EUROSTAT questionnaire: “Innovation co-operation means active participation in joint R&D and other innovation projects with other organizations (either other enterprises or non-commercial institutions). It does not necessarily imply that both partners derive immediate commercial benefit from the venture. Pure contracting out of work, where there is not active collaboration, is not regarded as co-operation."

xii The importance of the collaboration is indicated by the fraction of companies in the group reporting that collaboration with the partner in question was of significant "merkittävä" or high "suuri" importance (category 3 and 2 of the 0 to 3 Likert scale).

xiii The innovation survey differentiates between 9 sources of knowledge: (i) sources from within the enterprise (ii) sources from within the enterprise group (iii) supplier, subcontractor (iv) clients and customers (v) competitors and companies of the same sector (vi) universities and institutions of higher education (vii) governmental and non-profit research institutes (viii) conferences, meetings, literature (ix) exhibitions and fairs.

xiv As no sectoral variables are significant in the analysis of Fritsch and Lukas (2001) their findings would not support this relationship. Thether (2002), however, shows that collaboration with customers is more likely in high-technology sectors.

xv Universities may be chosen as a collaboration partner simply because other partners are not available or collaboration with other partners is not desirable from the firm's point of view.

xvi We will not make use of the representativeness of the survey, as we do not intend to aggregate our results to the national level.

xvii The numbers in brackets give the Finnish industrial classification 1995, for each company in the innovation survey we retrieved the industrial classification from the business register and transformed it into the Finnish industrial classification of 1995, where necessary.

xviii Principal component analysis generates continuous variables with a zero mean and a unit variance for every year. We can now compare the variables as we can now reasonably assume that they have the same scale.

xix In particular we used the stepAIC procedure that optimizes the AIC of a given regression model. It is available for S-Plus and R (cf. Venables & Ripley 2002).

xx We do not consider the survey 1991, when looking at the service sector as it is only targeted towards manufacturing companies.

xxi Additional information about the characteristics of the sectors summarized by the high-technology manufacturing is necessary to track this result back to its origins.

xxii Table 4-2, Table 4-3 and Table 4-4 can be found starting on page 65.

[xxiii] Based on Haagedoorn and Clodt (2003) we use patents as a proxy for innovative output.

[xxiv] Details about the generation of the grouping variables can be found in Section 4.4.1.

[xxv] Had we not done so, all foreign-owned firms would, by definition, be part of a foreign owned corporate group. Only a fraction of the domestic-owned firms, are part of a corporate group, though. Observing a difference between foreign-owned firms and domestic-owned firms would in this case also include the effect of group membership. To eliminate this effect we only analyze firms that are part of a corporate group. Hence in talking about firms we implicitly mean firms belonging to a corporate group.

[xxvi] In the discussion below we also use the term domestic mononationals to refer to the companies that are domestic-owned and not grouped into the domestic multinationals category.

[xxvii] We exemplarily report the selection equation of the selection model regressing the innovation input. The findings here hold for the selection equations in all other regression models testing the other gap hypotheses.

[xxviii] The marginal effects are computed at the sample means (Greene 2000, p. 816).

[xxix] For the definition of high, medium-high, medium-low and low-technology manufacturing, see Hatzichronoglou (1997).

[xxx] See OECD (2001) for the classification used.

[xxxi] We only base the empirical analysis on companies that reported successful or unsuccessful innovation efforts. In the CIS data, successful innovation efforts are indicated by dummy variables about the firms' realization of product or process innovation. Unsuccessful innovation activities are captured in the dummy variable indicating that the firm has abandoned its innovation projects.

[xxxii] For the purposes of brevity, these tests are not reported here. They are available upon request.

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Abstract
This study summarizes the research on the innovation activities of Finnish firms and its many facets drawing on vast data supplied by Statistics Finlands, register and survey data. The authors set out to analyze the impact of public funding, the pattern of collaboration for R&D and their determinants, the impact of foreign ownership on innovation activities and firm performance, and, finally, the returns from innovation, their determinants and distributions.

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VTT PUBLICATIONS 558 Pattern of Innovative Activities among Finnish Firms Bernd Ebersberger & Olavi Lehtoranta

This report summarises the research on the innovation activities of Finnish firms and its many facets. The authors set out to analyse the impact of public funding, the pattern of collaboration for R&D and their determinants, the impact of foreign ownership on innovation activities and firm performance, and, finally, the returns from innovation, their determinants and distributions.

The data sources used are the different waves of the Community Innovation Survey (CIS 1 through CIS 3), the Database of Finnish Innovations from VTT Technology Studies, and various register-based data sources from Statistics Finland, such as the business register, patent register, employment register and the like, and data on companies receiving funding for R&D supplied by the National Technology Agency of Finland (Tekes).

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