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Abstract

The aim of this study is to analyse the dynamic effects of innovation and collaboration in innovation on the growth performance of Finnish firms. We are mainly interested in the long run (5 years) average annual growth rates of innovative firms. We first review the literature on growth theories of firms and on the empirical research on innovation and firm growth. Then we conduct partial panel data analyses of the determinants of growth in sales, employment and productivity for firms included in the Finnish Community Innovation Surveys (CIS). Besides collaboration in innovation, we also utilize existing data on the corporate spin-offs of large manufacturing firms. We use two waves of the CIS, CIS2 and CIS3, and link them separately with growth performance data taken from the Business Register, with patent data taken from the Patent Register and with education data taken from the Employee-Employer Dataset.

We use the Heckman two-step selection model together with a single-equation OLS and ML estimation method for the long run growth rates of firms, and a variant of the Crepon, Duguet, Mairesse (CDM) structural model for the productivity levels of firms. We obtain only partial evidence that process and product innovations affect significantly and positively the post-innovation total sales growth among innovation active firms. Similarly, we find only partial evidence that collaboration in innovation with foreign competitors and being established as spin-offs of large firms affects the total sales growth. Nonetheless, the relationship between the occurrence of innovations and the future productivity growth of innovative firms comes out as a robust result.

Preface

This report summarizes the results of the research project "From Innovation to Economic Growth: Factors Contributing to Longer-Term Success of Finnish Innovators" carried out with funding from Tekes (Finnish Funding Agency for Technology and Innovation). Simultaneously, it intends to serve as an orientating background paper in economic studies of the author on the impact of internationalization and overseas knowledge flows on Finnish SMEs and innovation systems. The principal target for these studies has traditionally been in analyzing the performance of firms and sectors.

Many commentators have contributed to this work. First of all, I want to thank Dr. Annaleena Parhankangas (New Jersey Institute of Technology, USA) and M.Sc. (Eng.) Pasi Kuusela from Helsinki University of Technology for a good and pleasant collaboration in identifying and analyzing corporate spin-offs in a collaborative project between VTT, Helsinki University of Technology and Statistics Finland. I also want to express my gratitude to my colleague, Dr. Mariagrazia Squicciarini for joining with me in the OECD Micro Data Projects on Innovation and Productivity and on Innovation and IPRs. Many ideas on how Community Innovation Surveys could be best utilized are stemming from this collaboration. Then, I am also grateful to my previous colleague, Dr. Bernd Ebersberger (Management Center Innsbruck, Austria) and my present colleague Nina Rilla, researcher at VTT, not only for commenting on this study but also for helping in establishing the target study on the internationalization of knowledge and innovation activities. My acknowledgements also go to Robert van der Have, researcher at VTT, for checking the language of this report, to Kaija Hovi, former Director of the Business Structures at Statistics Finland, to Heli Talja, Chief of Technology, and Torsti Loikkanen, Research Coordinator at VTT for their manifold encouragement. The stimulating steering group of the collaborative project is also worth mentioning here, and the financial support from Tekes is gratefully acknowledged.

Espoo, February 2010

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Contents

Figures and tables

1. Introduction

1.1 The types of manifestation of corporate growth

The growth of a firm gets its manifestation as an increase in its market share, an expansion of its market area (organic growth), a development of its business activities towards new directions (diversification) or as an expansion through mergers and acquisitions. Growth can also be materialized through changes in enterprise boundaries (e.g. insourcing of subcontractors) or through the contribution of strategic partnerships and networks. A firm can also grow by selling its product concepts (franchising). Internationalisation has been regarded as one way to grow especially for firms operating in small markets. At least three groups of internal factors affecting the growth of firms can be distinguished: the characteristics of firms, entrepreneurs, and strategies related to the growth and management (KTM 2005). In choices of strategy a Porterian growth (Porter 1990) is based on efforts to become a cost leader, to differentiate or to focus (Malinen and Toivonen 2005).

1.2 The growth capacity and growth potential of a firm

The growth capacity of a firm is defined to consist of its strategic competencies, innovativeness and business competencies. The competitive edge of a firm, for its part, may be based on innovation, competence, strong brand or customer orientation. The growth potential of a firm can be based on its competitive power in markets, demand or supply conditions (Hyvärinen and Rautiainen 2006). The determinants of corporate growth can be studied from the viewpoint of business economics: from the angle of a firm's internal resources and strategic growth orientation (Borch et al. 1999; Storey 1994; Heinonen 2005). The resources are comprised of permanent like competencies, routines and knowledge. The growth capacity of a firm refers often to its resources and competencies, and the growth potential to its operational environment.

1.3 Innovativeness and external growth potentials

The determinants of corporate growth can also be studied from the angle of economics, where the external growth potentials and innovativeness as well as the collaboration between firms are in the main focus (see e.g. Folkeringa et al. 2004; Baldwin and Gu 2004; Baldwin and Gellathy 2003). Evolutionary growth theories emphasize the path dependence of firms, the dependence of the growth of a firm on the previous history of a firm or entrepreneur. Evolutionary theories also give an explanation for why the growth of firms can happen with bursts. The strategic and structural factors (market structure) affect the growth of the firms and the whole economy. The organisational innovation theories, in their part, emphasize the consideration of the complexity and non-linearity in the distribution of work (internationalization, global competition) as well as in the typology of organisation and innovation (see Nooteboom 1994). Theories, therefore, provide quite many routes to the core of the corporate growth (Heinonen 2005). Innovation activities and especially product innovations and the education of personnel and management and the networking of firms have been discovered to have a positive influence on the corporate growth (e.g. Tsupari et al. 2004). New markets, new technology and improvements in the production efficiency (novelty creation) have been detected to have even a stronger effect on corporate growth (Baldwin 1996; Johnson et al. 1997; Baldwin and Johnson 1998). The growth path of a firm or a group of firms over years can be seen as a series of annual growth realizations, including fluctuations and random walk due e.g. to business cycles, technology cycles and other reasons, but also of growth bursts over a few years. Post-innovation growth bursts can be expected especially after some successful innovations. But not all innovation is expected to have the same impact on firm performance. Innovation differs depending whether they involve new products, new processes or some combination of these two. Innovation also differs in terms of novelty.

1.4 Innovation and firm growth, main focus on small and medium sized firms

As stressed by Cohen and Levin (1989), innovation studies typically overlook the effect of innovation on firm growth. According to Nelson and Winter (1982) firm growth is related to its ability to innovate. In her empirical study, Lindholm (1994) finds that innovativeness and technological competence is related to the growth of firms. When using a survey of entrants, Baldwin and Johnson (1998, 1999) report that in new firms, growth in output is closely related to innovation. Also Baldwin et al. (1994) find that the key characteristic that distinguished the more successful small and medium-sized firms from the less successful SMEs in terms of firm growth is the degree of innovation taking place in a firm. Recently, Coad and Rao (2008) observe that whilst for the "average firm" innovativeness may not be so important for sales growth, innovativeness is of crucial importance for the "superstar" high-growth firms. The introduction of product innovations normally results in a new demand, and that of process innovations in a reduction of costs. Both elements affect the growth process of the innovating firm positively.

1.5 The aim of the study

According to Mairesse (2006) "There is no need for statistics and econometric analyses to be convinced that research and innovation make an important contribution to corporate performance... Statistics and econometrics are necessary, however, to measure these contributions quantitatively and to assess whether public and private investment in basic and applied research and development (R&D) and in innovation are adequate or not, and whether their private and social returns are high." Following this view, the aim of this study is to analyze – not whether innovation has a contribution to firm performance but rather – why some innovating firms have a remarkably better growth performance than others. Does the type and nature of innovation explain all this? Is the origin or background of the innovating firm (e.g. corporate spin-off) a determinant for these growth rate differences? Finally, what is the role played by the changes in the economic environment and network relations in the successful commercialization and exploitation of innovations?

Many earlier studies reveal that innovative firms are more successful than non-innovative firms and that spin-off firms are more successful than other new firms (Nås et al. 2003; see also Klepper 2001). Technology related spin-off firms are in many cases innovative as well. In the evolutionary theorising the endogenous growth process is typically seen as an historical, irreversible and cumulative process that considers economic dynamics as a bottom-up process and analyses the co-evolution of macro-dynamics, enterprise dynamics and technical changes (for a review of the evolutionary models of the economic growth, see e.g. Llerena and Lorentz 2004). In a similar vein our analysis considers the characteristics of innovations and innovating firms, the accumulation of technological knowledge over time and changes in the economic environment as factors contributing to the longer run growth performance of the small and medium-sized firms (entrants) and of the incumbent firms.

The positive relationship between strategic renewal and innovation by incumbent, existing firms and the performance of these firms, both in the short and long run, is only a rather weak stylized fact. Furthermore, it is not clear which aspects are in fact most important for achieving firm growth (Klomp and van Leeuwen 2001; Janz et al. 2004). Researchers are still to some extent uncertain why some firms grow and others do not when originating from similar circumstances.

Table 1. Research questions.

1. The aim of this study is to analyse the dynamic effects of innovation and collaboration in innovation on the growth performance of Finnish firms.

2. The focal question is why some innovating firms have a remarkably better growth performance than others do. Does the type and nature of innovation explain this? Is the origin or background of the innovating firm (e.g. corporate spin-off) a determinant for these growth rate differences? What is the role played by the changes in the economic environment and network relations (collaboration in innovation) in the successful commercialization and exploitation of innovations?

Rationales

Researchers are still to some extent uncertain why some firms grow and others do not when originating from similar circumstances.

This approach is reasoned especially for small firms and new entrants which have introduced their first major innovation within the reference period. It is also justified for other firms that are renewing their products and processes. The fruits of this renewing process typically show up in periods related to the product cycles of the firm.

Theories

Stage theories of corporate growth, product cycles of the firm, models of endogenous firm growth, the growth and innovation literature.

1.6 Partial panel data analyses over two waves of CIS

The aim of this study is to analyse the dynamic effects of innovation and collaboration in innovation on the growth performance of Finnish firms. We are mainly interested in the long run (5 years) average annual growth rates of innovative firms. We first conduct a literature review on the growth theories of firms and on the empirical research on innovation and firm growth. Then we carry out partial panel data analyses of the determinants of long run growth in sales, employment and productivity for firms included in the Finnish Community Innovation Surveys (CIS). Besides collaboration in innovation, we also utilize existing data on the corporate spin-offs of large manufacturing firms. We use two waves of the CIS, CIS2 and CIS3, and link them separately with period-specific growth performance data taken from the Business Register, with the patent data taken from the Patent Register and with the education data taken from the Employee-Employer Dataset. CIS2 refers to the period 1994–1996 and CIS3 to the period 1998–2000.

Here, innovative (innovation active) firms have been defined as firms that have introduced an innovation or have ongoing or abandoned innovation projects during a three years reference period given in the CIS. This definition corresponds to the filter question used in the questionnaire. We do not use innovation expenditures or innovative sales as criteria for innovativeness for many reasons. First of all, innovation expenditures of firms are often quite unreliable, especially for firms that do not report any innovative sales during the reference period, and are sometimes not even checked in the Finnish CIS. The main effort in these surveys has been put on the dichotomous variables of being innovative or not.

Table 2. Definitions.

Innovative firms

Innovative firms have been defined as firms that have introduced an innovation or have ongoing or abandoned innovation projects during a three years reference period given in the CIS (Oslo Manual, OECD 2005). We do not use innovation expenditures or innovative sales as criteria for innovativeness for data quality reasons. We use innovation expenditures and innovative sales in some models (e.g. in a variant of the CDM model) only for comparison purposes.

Rationales

We believe that in the CIS the quality of innovation expenditures and innovative sales is not as good as is the binary information on innovativeness. Data replacement and imputation are not used in questions on innovation activities. By using binary information on product and process innovations we avoid problems related to intramural and extramural R&D expenditures. Firms may well introduce innovations without intramural R&D, and data on extramural R&D expenditures may not be reliable. In addition, in the CIS data innovation expenditures and innovative sales only refer to the latest year of the reference period.

References

Baldwin et al. (2004) point to the difficulty to measure the amount of sales that come from a product innovation, especially if the innovation is incremental and is an add-on to an existing product.

The growth studies of individual producers usually inherit problems caused by the selectivity and non-randomness of the data sets, short time periods over which growth performance is considered, and the lack of real panel data on the growth determinants. These all will cause biases on the significance of these determinants and the size of the effects. In this study, we have tried to minimise these biases by using Heckman selection models (Heckman 1979) and average annual growth rates over the 5 years periods before, during and after the innovation period. In addition, CIS data have been used in a way enabled by the quality of the data.

Most innovation studies based on the CIS relate innovation in a period to growth in the same period. However, during the period when the innovation is introduced, there is probably a smaller difference in the growth in sales, productivity and employment between innovating and non-innovating firms or between product innovators and process innovators than after innovation. The effect of innovation shows up mainly in the post-innovation period rather than in the innovation period. If there is no product or process innovation or innovation project in the reference period, a firm is judged to be non-innovative. This approach for estimating the effects of innovativeness is justified especially for small firms or entrants in their early phases (Baldwin and Johnson 1999).

Table 3. Empirical analysis.

1. We conduct partial panel data analyses of the determinants of long run growth in sales, employment and productivity for firms included in the Finnish Community Innovation Surveys (CIS).

2. We are mainly interested in the long run (5 years) average annual growth rates of innovative firms.

Rationales

The growth studies of individual producers usually encounter problems caused by the selectivity and non-randomness of the data sets, short time periods over which growth performance is considered, and the lack of real panel data on the growth determinants. These all will cause biases on the significance of these determinants and the size of the effects. We have tried to minimise these biases by using Heckman selection models and average annual growth rates over the 5 years periods before, during and after the innovation period.

Most innovation studies based on the CIS relate innovation in a period to growth in the same period. However, the effect of innovation shows up mainly in the post-innovation period rather than in the innovation period. We relate past growth to the successful innovation during a subsequent period and successful innovation to the post-innovation growth performance. The panel data on firm performance allows us to examine the dynamic interaction between innovation and firm performance.

References

Baldwin and Gu (2004) use the similar approach when examining whether innovation is linked to firm performance. Also Klomp and van Leeuwen (2001) use similar performance measures what we are using: the average growth rates for total sales, productivity and employment. Also Harabi (2003) use the average annual sales growth rates, given here in log percentage points and expressed in an index form. Merz et al. (1994) contend that entrepreneurship might be best measured by combining two components of revenue change: average annual sales growth rate and sales variances over some time period.

As shown in Figure 1, innovation output may contribute to the post-innovation total sales growth through productivity growth, increase in the market share or market expansion. Figure 2 outlines somewhat different channels from innovation to productivity.

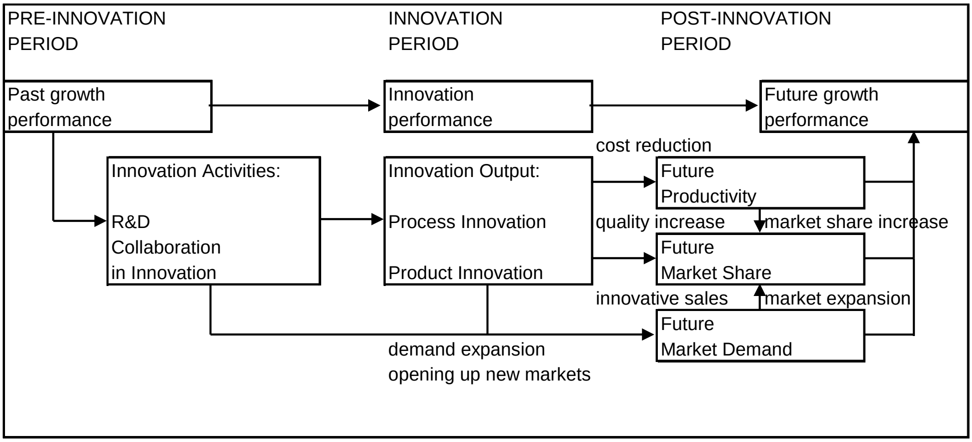

Figure 1. A stylized chart on the determinants of post-innovation growth.

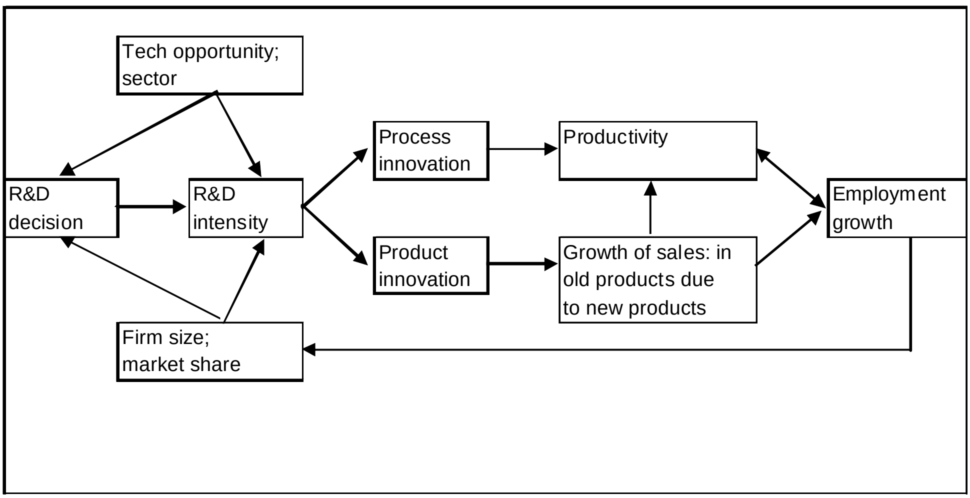

Figure 2. A possible encompassing CDM model with innovation-employment equation (Mairesse 2006).

2. Growth theories of firms

2.1 Models of optimal firm size

Rather than understanding the growth process, the majority of studies on firm growth have focused on explaining changes in size. There is a long tradition of the determinants of the optimum size of firms. Models of optimal firm size postulate that profit-maximizing firms can achieve an optimal size if they behave rationally. Optimal firm size depends on the market structure in which the firm operates. In perfectly competitive markets, firms with a U-shaped average cost curve will grow until they reach the size corresponding to the lowest point on the curve (Harabi 2003).

Relaxing the assumptions of the neoclassical theory of the firm permits many other explanations of firms' growth. If firms have market power then their optimal size may differ from the minimum cost position, and, if economies of scope exist, such differences may be more noticeable and firms can introduce new product lines (Geroski 2000). Product diversification is therefore another determinant of firm growth. More recent arguments have suggested that the degree to which costs are sunk and the intensity of competition may also be important determinants of firm size and market structure. Further, many believe that internal organizational factors may be as important as market competition and technology in determining firm size.

2.2 Stage theories of growth

Besides models of optimal firm size, there are stage theories of growth. In stage theories a firm's goals may change over its life cycle. In fact, there have been numerous attempts over the years to identify life cycles of firms, model their evolution or at least pick out identifiable stages through which they grow. Mueller (1972) argued that what a firm does (i.e. sacrifice profits for growth) varies with age. A strictly profit maximizing firm is likely to enjoy only a finite burst of growth associated with each innovation. Stage theories of growth have some basis in facts and are often a useful aid to conceptualization. However, according to Geroski (2000), the basic problem with these arguments is that they are built up around the view that there are deterministic trends in the pattern of growth of firms. The "fact" is that growth rates display stochastic trends, and since the data on growth displays very little in the way of transitional dynamics, there is no meaningful distinction between short and long run to be found in the data. In neo-classical theory there is no justification for the life cycles of firms.

A somewhat more modern and more formal version of the stage theories starts from the realization that a firm faced with variable adjustment costs will have an incentive to being adjusting to shocks which it expects to occur in the near future. This means that its optimum size will depend, inter alia on cost and demand conditions which are expected to prevail in the near future. Since, in this simple model, growth is driven by current changes in expectations, this means that growth rates are unpredictable. The history dependence displayed in growth rates arises from the fact that each burst of growth has a permanent effect on the size of the firm. The history dependence displayed is one in which the realized outcomes of current decisions depends on the realized outcomes of previous decisions. These are quite different types of "history dependence" (being permanent and transitory), and the "facts" fit more easily with the former than with the latter.

2.3 Models of industry dynamics and industry life cycles

Instead of assuming a purely stochastic process of firm growth, the models of industry dynamics by Jovanovic (1982), Lambson (1991), Hopenhayn (1992), Cabral (1995), Ericson and Pakes (1995), Pakes and Ericson (1998) describe the patterns of growth and failure characterising individual businesses and are based on profit maximisation. These models are useful in explaining differences in firm heterogeneity and market structure, including firm growth and turbulence, across different time periods and industries.

Based on the fact showing that within an industry smaller firms grow faster and are more likely to fail than large firms, Jovanovic proposes a theory of selection with incomplete information in which efficient firms grow and survive and inefficient firms decline and fail (Lööf 2002). According to Jovanovic‘s theory, firms need adjustment time to uncover their true efficiencies, so that a negative relationship emerges between firm age and growth and a positive relationship between age and survival. The model implies that Gibrat's law[1] holds for the mature firms and for firms that entered the industry at the same time. An additional implication is that the variance of growth is largest among young and small firms.

2.4 Models of industry evolution with sunk costs and uncertainty

Lambson (1991) presents a model of industry evolution with sunk costs and uncertainty. In this model firms face exogenous shocks to demand or input prices, which occur at infrequent intervals. The model predicts that industries with high rates of turnover should be characterized by low sunk costs and high elasticity of substitution between inputs. Hopenhayn (1992) develops an industry equilibrium model of turbulence and firm dynamics. In his model the only sources of uncertainty are the firm-specific productivity shocks, which follow a Markov process. The model also predicts the evolution of the firm size distribution by age cohorts. Under certain assumptions, the model is consistent with the negative relationship observed between firm size and growth, at least for small firms (Nurmi 2004).

2.5 Models of firm size, growth and sunk costs

In the Cabral's (1995) model on firm size, growth and sunk capacity costs, firms with a higher efficiency are larger, both in terms of the level of employment and output. A passive learning process similar to the models of Jovanovic (1982) and Hopenhayn (1992) is assumed. Productivity in period 1 provides a signal of the future productivity. The exit of slowly growing small firms from the sample may cause the relationship between size and growth to be biased downwards. Cabral shows that Gibrat's law holds when this sample selection bias is corrected. In contrast, the expected growth of surviving firms decreases with size. Cabral then includes sunk costs in the model to show that even correcting for the sample

[1] Gibrat's law predicts that expected growth rates are independent of firm size.

selection bias, a negative relationship between size and growth emerges when there are sunk capacity or technology costs.

In the models by Lucas (1978) and Rosen (1982) the emphasis is on the human capital of managers, whereas in the model of Kremer (1993) human capital is defined as probability of a worker successfully completing a task. Cabral's (1995) model can be modified to take into account investments in human capital that involve some degree of sunkness. Hence, if it is assumed that small firms have a lower likelihood of survival, the inclusion of sunk costs implies that small firms grow faster than large firms. Thus, the model implies a negative relationship between initial size and expected growth. Higher adjustment costs related to human capital increase the relative growth of firms. Since recruiting higher-skilled labour may be more costly, this result implies that firms with higher labour quality have higher growth rates.

The model of Pakes and Ericson (1995, 1998) offers an analysis of firm and industry dynamics as a steady state phenomenon within a game-theoretic setting. This model is based on an active learning process, where profit maximising firms can affect their productivity by investing in R&D activities. However, due to firm-specific uncertainty, firms cannot predict what the effect of investments on their productivity is.

2.6 Resources push theory of growth, managerial limits to growth hypothesis

Most of the interesting theorizing about the growth of the firm has been developed by Penrose (1959). She argued that the firm is basically a collection of resources and then analysed the process of growth in terms of the speed with which firms could accumulate and assimilate such resources. Basically Penrose's theory is a theory of innovative enterprise and thus appropriate for analyzing firms and industries that are characterized by innovation (Lazonick 2002). Technology-based firms are an example of such firms. The classic study of the growth of firms by Penrose contains two quite different types of arguments. One is a resources push theory of growth, and the other argument is her famous managerial limits to growth hypothesis.

According to Penrose unused resources and increase in knowledge would provide incentives and direction for further expansion. A central theme in Penrose's (1959) theory is that the continuation of the growth process is based on the identification of new opportunities for growth. Penrose argues that the increase in knowledge comes in two ways. First, knowledge increases due to learning by experience. This experience may be gained from the operations of the firm, or interaction with its customers. Second, knowledge increases due to search for new knowledge.

2.7 The resource, knowledge and competence based theory of the firm

Central concepts of Penrose's theory have been used and developed further within three highly related research streams: the resource-based view of the firm (Wernefelt 1984; Peteraf 1993), the knowledge-based view of the firm (Kogut and Zander 1992, 1996; Spender 1996; Grant 1996; Loasby 1998; Nonaka et al. 2000) and the competence-based view of the firm (Prahalad and Hamel 1990; Pisano and Shuen 1997; Dosi and Marengo 1994; Foss and Knudsen 1996). What is common to all these three fields is the assumption that firms are heterogeneous entities that evolve in a cumulative way. Hence, their competitive advantage is based on the results of this evolution in terms of their resource and knowledge endowments.

The competence-based view is more concerned with dynamic issues than the other two are. Researchers have stressed the importance of competencies and capabilities that are dynamic, in the sense that they enable the firm to adjust to changing environments. The competence view is concerned with sustainable competitive advantage, similarly to the resource-based view, and stresses the knowledge coordinating aspect of the organization that is central in the knowledge-based view. Loasby (1991) and Foss (2002) have argued that the essential Penrosian point is the importance of knowledge development and management for growth. Penrose emphasized the importance of the resource base and adaptive capabilities for competitive advantage. It follows that Penrose's (1959) theory has had more impact on theorizing about strategy and competitive advantage than on studies related to growth.

2.8 Models of organizational capabilities

In Penrose's theory of growth, much attention is given to the basic process of accumulation of resources and the related accumulation of knowledge. Chandler (1962, 1992) argued that "knowledge accumulation of management was essential for developing the organizational capabilities needed for taking advantage of external opportunities made available by demographic and technological changes. These capabilities are created during the learning process involved in bringing a new or greatly improved technology on steam, in coming to know the requirements of markets for new or improved products, the availability and reliability of suppliers, the intricacies of recruiting and training managers and workers.” (Chandler 1992, p. 487), (see Geroski 2000). Penrose was more concerned than Chandler with how knowledge development within the firm is central for the identification of opportunities for further growth.

2.9 Critics against the most common theoretical models

Recent models of organizational capabilities are highly related to Penrose's theory. The basic premise of these models is that competitive advantage is based on the possession of a few key resources and routines, organizational capabilities or core competencies. It follows that firms are likely to be heterogeneous and realize different levels of performance over long periods of time because competencies are unique or difficult to imitate (Malerba 2006). For example, Teece (1980) argues that organizational practices affect firms’ performance and can explain sustained performance differences within industries due to slow diffusion of best practices and difficulties in imitating complex organizational capabilities.

However, according to Malerba, the argument that corporate growth is driven by competencies is not consistent with the “facts“. The basic problem is that most of the literature on competencies has sprung up to explain persistent differences in corporate performance between firms, but firms do not display persistent differences in their growth performance. Corporate growth rates differ between firms in temporary and unpredictable ways. The consequence of all of this is that theorizing about competencies is being driven by a correspondence with the “facts” which is, at best, partial.

According to Malerba (2006), it is an open question whether organizational capabilities really explain performance differences between firms. Following the argumentation of Malerba, “more interesting is the question of which performance differences between firms they explain; that is, whether growth or innovative activity returns. Among other things, this means asking whether competencies really are hard to imitate or are durable; that is, whether certain competencies sustain only short run performance differences between firms while others sustain differences over the long run. It is, of course, possible to argue that exogenous factors are entirely responsible for the unpredictable nature of corporate growth rates, but this is hard to believe. Many firms do not react quickly or well to market shocks, and others try to resist innovation. This inertia makes the timing of corporate activity difficult to predict, and, hence, it often makes corporate behaviour seen erratic. To understand the sometimes unpredictable birth and limited life of competencies, we will need to look more closely at how companies learn, and at how knowledge diffuses between firms".

To sum, Geroski (2000) finds that the most common theoretical models on firm growth are inconsistent with testable data. Geroski explores four basic types of theories of the growth of firms: (i) steady state firm size, including convergence to some equilibrium level, (ii) the life cycle model, (iii) a model based on Penrose's managerial limits to growth hypothesis, and (iv) the resource-based theory of the firm. He finds that differences in firm size and heterogeneity in growth rates are permanent. On the other hand, in his survey on firm growth models, Sutton (1997) finds that the new generation of models in the "random walk framework" is still stochastic but that the source of randomness has either been pushed backwards into a description of a firm's "intrinsic efficiency differences", or forward into random outcomes emanating from R&D programs (Lööf 2002).

2.10 The growth and innovation literature

The growth and innovation literature provides many alternative conceptualizations and models to understand observed data and established stylized facts about the behaviour of firms. In the following we briefly review some previous research on innovation and growth by looking at the Schumpeterian literature. Then we present a new theoretical model of endogenous firm growth with R&D investment and stochastic innovation as engines of growth that fits the empirical findings very well.

The Schumpeterian branch of economic literature puts forward two distinguished models for analyzing firm growth. The first model views technological change as a process of creative destruction. The typical innovators are expected to be small and newly established firms. The second model emphasizes that technological change is a process of creative accumulation. The role of new innovators is limited, and a few large firms determine the market in a stable monopoly. Nelson and Winter (1982) and Ericson and Pakes (1995, 1998) however, show that these two alternative representations of the pattern of technological change can be interpreted as two faces of the stochastic process which drives technological accumulation at the firm level and thereby drives the dynamics of the industry.

2.11 A Schumpeterian version of the endogenous growth model

Contrary to the neoclassical model, the growth economics tries to explain economic growth explicitly by new goods and increased knowledge intensity in the production process. Based on the endogenous growth model outlined by Romer (1990), Aghion and Howitt (1998) present a model of innovation and capital accumulation, i.e. a Schumpeterian version of the endogenous growth model. Their model predicts that long run growth should be positively correlated with R&D productivity, the flow of patents and new products and should decrease with the rate of depreciation of human and physical capital. Also Klette and Griliches (2000) have proposed a model of endogenous firm growth, inspired by the macro-models of endogenous growth, in particular the quality ladder model. In their model R&D and innovations are the engines of growth.

2.12 An adapted Dixit and Stiglitz model of monopolist competition

Baldwin and Gu (2004) present a formal theoretical model on the link between innovation, productivity growth and market-share changes. It adapts Dixit and Stiglitz (1977) model of monopolist competition to allow for the choice of innovation and R&D. Authors report that although this modelling approach has not been used in most previous studies of innovation, it is quite common in the international trade literature (see Melitz, 2003). The model is consistent with two main features of data for individual firms. First, there is large dispersion in prices across firms. Second, there are large and ongoing shifts in market shares across firms. The ongoing shifts in market share are a key prediction of the model that allows for innovation and R&D. A firm in the model is characterized by output production function, production function for process innovation, production function for product innovation, and total cost equation. Badwin and Gu choose R&D investments over the firm's lifetime to maximize its discounted profits. The market share of a firm is linked to process and product innovations. Process innovation increases market share through its effect on the cost and price of the output, whereas product innovation raises market share through its effect on the consumer's demand. Process and product innovations both have a positive effect on the productivity growth. Furthermore, firms with higher productivity level and faster productivity growth tend to grow faster and gain market shares. High substitutability across products increases the incentive to innovate. The model will have a basic structure that is similar to the model of Ericson and Pakes (1995). Productivity, product quality and thus revenue of a firm are assumed to follow a probability distribution. A firm's investment in process and product innovation is assumed to increase the revenue of the firm through its impact on productivity and product quality. The model can also be extended to allow for the effect of past growth performance on innovation.

2.13 The state of art in theorizing corporate growth and the evolution of industries

There are various empirical and theoretical strands in the literature, from the old debate regarding demand pull vs. technology push (Schmookler 1966), to the analysis of demand, market structure and innovation (from Kamien and Schwartz 1975 to Sutton 1981, 1998), imperfect information among consumers, user mitigated innovation (Von Hippel 1988), user-producer interaction (Lundvall 1988) and value networks (Christensen and Rosenbloom 1995). The presence of submarkets plays a role in affecting the growth and size distribution of firms within an industry, as Klepper and Thompson (2002) show for the laser industry. Demand has been a key with respect to the emergence of disruptive technologies, as Christensen (1997) has documented in. Finally, as pointed out by Malerba (2006), when demand and innovation is examined, one has to mention the whole literature on diffusion: all the major empirical advancements and theoretical models regarding diffusion are nothing but contributions regarding the demand of innovation. The same holds for the literature on competing technologies, which pays attention to externalities and increasing returns.

2.14 The role of demand in the evolution of industries

At the empirical level, the role of demand during specific stages of the evolution of an industry has been shown to be relevant. Standard economic analysis claims that demand provides incentives to innovation during industry evolution. According to Malerba, one could also add that, in terms of incentives, demand is not homogeneous. It is highly heterogeneous in terms of segments, types of firms and individual customers. In addition, the knowledge and mental frameworks of consumers and users greatly affect innovation and performance. There is also learning and knowledge growth in consumption, much of which is local. Consumer competencies play a major role in influencing innovation. Furthermore, the distribution of competencies among users greatly affects the dynamics of industries (Malerba 2006).

According to Malerba, the successful introduction of a radically new technology in an industry may be dependent on a group of experimental customers. This allows new firms with the new technology to be viable. A similar dynamics is played by potential customers with different preferences, when potential markets are not served by incumbent firms. Both cases of demand permit new technologies effectively to grow, either within established firms or through new firms. In this frame, the interaction between producers and users changes the capabilities and preferences of both producers and users, and sets in motion a co-evolution of technology, knowledge, market structure and innovation. In conclusion, the progress in understanding the relationship between demand, innovation and industry evolution calls for new challenges in terms of richer and more detailed empirical analyses, deeper appreciative understanding and formal modelling.

At the modelling level, the challenge is to examine theoretically some of the processes presented above. Broadly, one would like to model the links between demand dynamics, firm dynamics and technology dynamics. In fact, on the one hand, the emergence and development of new technologies create new markets, submarkets and niches. On the other, the dynamics of demand in terms of consumer learning may stimulate technological change and the entry of new firms. Adner and Levinthal (2001) model a co-evolutionary process in which there is a demand life cycle: early on product innovation increases performance but then process innovation takes over.

2.15 Knowledge and innovations in the evolution of industries

For Schumpeter, innovation was very closely linked to the emergence, growth and decline of industries. After Schumpeter there was a shift of attention away from industrial dynamics towards the relationship between innovation and firm size, on the one hand, and innovation and market structure, on the other. With the advent of game theory, the focus moved to firms' strategies in R&D and licensing (Malerba 2006). Then, progress has been obtained in examining the extent and effects of heterogeneity of firms in terms of different knowledge, competencies and learning processes. Industries have been interpreted as systems, in which actors are related and interact in various ways and are strongly influenced by their competencies, learning processes, the knowledge base of sectors and the institutions.

At the modelling level, different strands have developed, in various ways and directions. At one extreme, one can find models of industry dynamics with rational actors and technological learning by incumbents or entrants or both, and the competitive process weeding out the heterogeneity in firm populations (see for example, Jovanovic 1982; Ericsson and Pakes 1995), with not much consistency with some stylized facts such as inertial asymmetric performance, irrational entry processes and so on (Malerba 2006). The evolutionary models a la Nelson-Winter have boundedly rational actors, learning and processes of experimentation and imperfect trial and error. Selection processes take place on a heterogeneous population of firms (Nelson and Winter 1982; Dosi and Nelson 1994). These models have a destrategizing conjecture, in that differences in structures and processes of change are understood as independent from firm micro strategies (Winter 2000).

In the formal models of industry life cycles product and process innovations, rate and type of entrants, selection, firm size and growth, market concentration and market niches have been analyzed (Klepper 1996, 2002; Klepper and Simons 2000). During its evolution, an industry undergoes a process of transformation that involves knowledge, technologies, learning, the features and competencies of actors, types of products and processes, and institutions. An industry also changes its structure, where the term "structure" here means not market structure, but rather the network of relationships (competitive and cooperative, market and non market, formal and informal) among actors that affect innovation and performance in an industry (Malerba 2006).

Evolutionary literature has proposed that sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation. In some sectors, science is the force driving knowledge growth, while in others, learning by doing and cumulativeness of advancements are the major forces. Knowledge has also different degrees of accessibility with major consequences on entry and concentration, and may be more or less cumulative. In addition, knowledge may flow more or less intentionally across individuals and organizations and links and complementarities have to be taken into account (Malerba 1992). Links and complementarities may refer to scientific, technological or application knowledge.

In analyzing the effects of networks one may proceed from static models regarding the effects of different network architectures on performance to dynamics of networks, to network evolution in which the focus is on processes and rules. The innovation system literature has put the role of links and relationships among various actors at the centre of the analysis (see Lundvall 1993; Edquist 1997; Teubal et al. 1991). In a similar vein, evolutionary theory has stressed that, in uncertain and changing environments, networks emerge because agents are different, thus integrating complementarities in knowledge, capabilities and specialization (see Nelson 1995). Also Freeman (1994) wrote about networks of innovators as driven by technological complementarities.

A related issue is how and why the specific features and characteristics of networks affect innovation, profitability and growth in an industry. According to Malerba, in this respect, we are still at the beginning of the research agenda. From exploratory empirical analyses it seems that strong ties favour exploitation and weak ties favour exploration. But additional robust evidence and deep appreciative theorizing on this and other connected issues are needed.

Table 4. Determinants of corporate growth, theoretical arguments.

Steady state firm size models suggest that firm size depends on the market structure. Relaxing the neoclassical theory permits many other explanations: market power, economies of scope, product diversification, intensity of competition, organizational factors. In stage theories a firm's goals may change over its life cycle allowing growth spurts associated with innovation. In this context, sales growth is a meaningful indicator for post-innovation performance. Studies of early growth typically concentrate on sales.

The models of industry dynamics are useful in explaining differences in firm heterogeneity and market structure. They imply e.g. that efficient firms grow and survive. Other reasons for growth may include high substitutability of inputs and investments in human capital. Network of relationships among actors are predicted to affect innovation and performance in an industry.

Penrose highlighted unused resources and increase in knowledge, learning by experience and interaction with customers, and searching for new knowledge.

Counter arguments

Firms do not display persistent differences in their growth performance. Corporate growth rates differ between firms in temporary and unpredictable ways. Most common theoretical models are inconsistent with testable data.

New models

New generation of firm growth models focuses on random outcomes emanating from innovation efforts. The models of endogenous firm growth predict that long run growth is positively correlated with R&D productivity, the flow of patents and new products. They also predict that past growth performance (and past innovation) affects innovation.

3. Findings from recent empirical research

3.1 Basic "facts"

Firm size follows a random walk; corporate growth is a path dependent process

Geroski (2000) sets out some of the basic “facts” about the growth of firms which have been uncovered in recent econometric work. The most elementary “fact” about corporate growth thrown up by econometric work on both large and small firms is that firm size follows a random walk. Increases in firm size are driven by unexpected shocks and these shocks have permanent effects on the size of the firm. This means that corporate growth cannot be thought of as a process composed of a deterministic trend with some noise superimposed on it. The trend itself is stochastic. In addition, it implies that corporate growth is a path dependent process. That is, the size a firm reaches in any time t depends on the whole history of shocks, which it has been subject to.

Differences in firm size are permanent; adjustment costs seem to be fixed

The second "fact" is that differences in firm size are permanent. Firm size drifts unpredictably over time, and, as a consequence, predictions of it become increasingly uncertain when time t gets larger. The growth rates of any two firms are likely to be uncorrelated. That is, corporate growth rates are likely to be idiosyncratic. According to Geroski, this is a surprising observation, since common sense suggests that the growth rates of most firms should rise and fall with variations in the growth rate of the economy or at least of the industry they belong to. However, studies of company performance in cyclical downturns usually show that most of the effects of recessions are concentrated in a few firms; many companies are not substantially affected and some actually prosper during cyclical downturns. Corporate growth is history dependent and every firm seems to have its own history.

There are two further pieces of evidence which complement the “fact” that firm size follows a random walk. The first is that adjustment costs seem to be fixed and not variable. If adjustment costs are fixed, then firms have an incentive to “save up” their desired changes until it is worth to make them, and then they will make them all in one “big bang“. The evidence is that firms more typically make large but infrequent and clearly discrete changes in their operations (e.g. in employment and investment), and not continuous but small ones.

Characteristics of growth rates may be due to the unpredictable and stochastic nature of innovation success

The second piece of evidence is that most firms are irregular innovators, that is, very few firms produce major innovations or patents on a regular basis, or are rarely persistent innovators. However, if we focus on activities which lead to noticeable technical breakthroughs which are commercially successful (i.e. “major innovations“) or patents, then the data suggest that very few firms manage to produce a regular sequence of innovative outputs. The typical pattern is that firms will innovate every once in a while, opening up very long periods of time between successive innovations. Irregular innovative activity is likely to mean that the growth spurts experienced by firms will be unpredictable. According to Geroski (2000), it turns out that the “facts” discussed here cast some doubt on the usefulness of a range of models or hypotheses about corporate growth which have appeared in the literature. It seems that there is little more that we can say about firm growth rates apart from that they are largely unpredictable, stochastic, and idiosyncratic. However, as Geroski concludes, these characteristics of growth rates may be due to the unpredictable and stochastic nature of innovation success; i.e. that looking at firm level innovations could be the key to understanding firm level growth.

Gibrat’s Law predicts that expected growth rates are independent of firm size

Early contributions on firm growth focused on the empirical validation of Gibrat's Law. Taken in its simplest form, this law predicts that expected growth rates are independent of firm size. Regressions have found, in general, that growth patterns are characterized by a weak negative dependence of growth rates on size, leading us to reject Gibrat's Law. Although we are led to reject Gibrat's Law, it does appear to be useful as a rough first approximation (Coad and Rao 2008). Size does not appear to be a major determinant of the rate of growth.

Advertising expenditure, demand growth and industry concentration are observed to have a positive influence on firm growth rates

Attention has also been placed on the influence of other factors on firm growth. One classic research topic has been to investigate the influence of age on firm growth. Age is observed to have a negative influence on firm growth. Storey (1994), for instance, has noticed that older firms grow slower than younger firms. Looking at data on industry leaders, Geroski and Toker (1996) identify other variables that are observed to influence growth. Advertising expenditure, the demand growth of an industry, and also the industry concentration are observed to have a positive influence on firm growth rates. However, even though such explorations into the determinants of firm growth rates may obtain coefficient estimates that are statistically significant, the explanatory power is remarkably weak (Geroski, 2000).

There may be considerable lags between innovation and its commercial success

A major difficulty in observing the effect of innovation on growth is that it may take a firm a long time to convert increases in economically valuable knowledge into economic performance. The effects often occur with long lag and may vary significantly from one firm or sector to another and change over time (Mairesse and Sasseneou, 1991). Even after an important discovery has been made, a firm will typically have to invest heavily in product development. In addition, converting a product idea into a set of successful manufacturing procedures and routines may also prove costly and difficult. There may therefore be considerable lags between the time of discovery of a valuable innovation and its conversion into commercial success. We therefore expect that firms differ greatly both in terms of the returns to R&D and also in terms of the time required to convert innovation into commercial success. However, it is anticipated that innovations will indeed pay off on average and in the long term, otherwise commercial businesses would obviously have no incentive to perform R&D in the first place.

The influences of specific innovations on sales growth are short-lived; innovators are likely to grow more than non-innovators

How do firms translate innovative activity into competitive advantage? Early study by Scherer (1965) looks at 365 of the largest US corporations and observes that inventions (measured by patents) have a positive effect on company profits via sales growth. This suggests that sales growth is nevertheless a meaningful indicator of post-innovation performance. Geroski and Machin (1993) look at 539 large UK firms over the period 1972–1983, of which 98 produced an innovation during the period considered. They observe that innovating firms (i.e. firms that produced at least one "major" innovation) are both more profitable and grow faster than non-innovators. The influence of specific innovations on sales growth is nonetheless short-lived – "the full effects of innovation on corporate growth are realized very soon after an innovation is introduced, generating a short, sharp one-off increase in sales turnover" (Geroski and Machin 1993, p. 81). Contrary to Scherer's findings, they observe that innovativeness has a more noticeable influence on profit margins than on sales growth. This is also in contrast to the finding of Geroski and Toker (1996). They look at 209 leading UK firms and observe that innovation has a significant positive effect on sales growth. Furthermore, Roper (1997) uses survey data on 2721 small businesses in the UK, Ireland and Germany and shows that innovative products introduced by firms made a positive contribution to sales growth. A further clarification is made by Freel (2000) by considering 228 small UK manufacturing businesses and by observing that although it is not necessarily true that "innovators are more likely to grow", nevertheless "innovators are likely to grow more".

3.2 Stage theories of growth and models of industry dynamics

Firm growth is negatively related to firm size and age

A large literature has explored the proposition that smaller (younger) firms grow faster than larger (older) firms. Most of the recent studies on the post-entry performance of firms find that firm growth is negatively related to firm size and age, whereas firms' survival is positively related to current size and age (e.g. Evans 1987b; Dunne et al. 1989; Dunne and Hughes 1994). In Nordic countries, the relationship between firm size and growth has been studied, for example, by Persson (1999), Klette and Griliches (2000), Heshmati (2001), Johansson (2001), Davidsson et al. (2002) and Reichstein (2003).

Firms in growing sectors have higher growth rates

Theoretical and empirical studies suggest substantial inter-industry differences with respect to firm growth. Johnson and others (1997) find a close relation between growth dynamics within a sector and firms' growth rates. They argue that growth rates of firms in growing sectors should be higher than those of firms in stagnating or declining sectors. Young and growing markets are, as a rule, characterized by low barriers to entry, and thus by high rates of entry and exit. Individual firms therefore have different growth potentials as determined by their sector's life cycle (Harabi 2003).

3.3 Models of demand, market structure and innovation

A major source of firm growth is its ability to innovate

Theoretically, it is expected that strong demand for the firm's products will enhance its growth. In addition, firms in large urban centres are proposed to grow faster than firms in other locations. Agglomeration effects can produce positive externalities that affect the growth of firms.

Another major source of firm growth is its ability to innovate. The introduction of product innovation normally results in a new demand, and the introduction of process innovation in a reduction of costs. An increase in quality of and demand for innovative products entering the markets can increase the market share of innovating firms, which on its side may result in an increase in sales growth and in labour demand. Limits on the growth of firms in this world of constant returns are determined basically by demand.

A further source of corporate growth is market structure and a firm's ability to diversify both its existing products and services and its product mix. A major outcome of an industry's market structure is whether a firm can compete in product markets or not, i.e. whether firm has power to vary its market share and therefore its relative position in the market. Except location, also legal form and firm ownership have been noted as important for corporate growth (see e.g. Storey 1994).

The determinants of firm performance are size dependent

Econometric studies, and particularly studies of strategic renewal and innovation efforts (e.g. Kemp et al. 2003; Cohen and Levin 1989) point out that the determinants of firm performance are size dependent. Previous studies have also shown the non-linear size effects (e.g. Cohen and Levin 1989; Lööf and Heshmati 2002). Kangasharju (2000) studies the determinants of growth among small firms by taking into account firm age, entrepreneurial human capital and macroeconomic fluctuations. The empirical results of this study show that the effect of the relative education level of employees on growth is positive according to the ordinary least squares (OLS) estimates but negative according to the within plants specification. This is in accordance with the empirical finding that personnel structure is determined during the initial stages of the firm life cycle and does not change much over time. It is also found that technical and scientific university level education has a negative effect on productivity growth (Ilmakunnas and Maliranta 2003). One explanation may be that the technically-skilled personnel are more involved in R&D, whose effects on production are revealed with a considerable lag.

3.4 Models with Penrose effects

Managerial limits to growth – hypothesis

The ability of firms to obtain access to major inputs is of paramount importance for their growth. Such assets would include managerial inputs, reflecting Penrose's "managerial limits to growth" hypothesis. For example, business strategies that focus on product diversification and market share expansion are proposed to affect firm growth. There is also evidence that an explicit and sound growth strategy matters. Important points of such a strategy include the choice of the right location and legal form, and the choice of markets with sufficiently strong and expanding demand.

Growth is associated with having clear objectives

Burns and Myers (1994) published the results of a survey of over 1350 SMEs (employing less than 500 people) across Britain, France, Germany, Italy, and Spain, which identify what they termed “winners and losers”. The principal conclusions was that growth is associated with having clear objectives for where the company should be in three years, having a product or service that is better or differentiated. According to the findings of Burns and Myers, organic growth was the approach most often used by successful companies. Overall, they found that businesses were more likely to grow if they concentrated on quality, or provided something different from their competitors, rather than competing mainly on price.

The principal barriers to growth

Barber et al. (1989) outlined the principal barriers to growth. They were management attributes, lack of finance, and the external labour market and market structure. Berney (1994) has a broadly similar list. He writes that barriers to growth are the product (poor quality, wrong costs), funding (inappropriate funding/equity), physiological/ motivational factors (low levels of ambition, risk aversion, fear of loss of control), managerial deficiencies (finance, organisational, production, marketing), and movement policy (taxation, incentives). The primary long term obstacles were limited market demand, accessing new markets, and the cost and availability of finance.

3.5 Strategic renewal and innovation efforts

The role of small firms in economic growth has become increasingly obvious

It has been argued that competitive advantage is moved from large, established firms to smaller, younger firms (Audretsch and Thurik 2000; Baumol 2003; see also Folkeringa et al. 2004; Romer 1990; Aghion and Howitt 1998). In many studies the small firm is supposed to have an advantage in the earlier stage of the inventive work, and in less expensive and radical innovations, while large firms have an advantage in the later stage of scaling up innovations and in efficient marketing (Freeman 1974; Williamsson 1975; Roberts and Berry 1985). On the other hand, in many sectors, new technologies reduced the necessity of scale economies to arrive at competitive advantages (Meijaard 2001). In line with Nelson and Winter (1982) and Utterback (1994) the role of small firms in economic growth has become increasingly obvious, even dominating the evolutionary dynamics of the business sectors.

A number of requirements for growth

A number of studies have been carried out to assess the profile of entrepreneurs. The entrepreneur can be identified prior to start-up, when the firm reflects decisions made upon start-up, while strategy determines its rate of growth. The profile of the firm is a reflection of decisions taken by the entrepreneur. Storey et al. (1987) examined the motivations business people have for growth and suggested that it was either due to a desire to maximise profits, to increase personal income, to enjoy economies of sale, or to fulfil potential sales and asset possibilities. If a firm is to achieve sustained expansion, it must satisfy a number of requirements for growth: it must have access to additional resources, it must expand its management team, and it must extend its knowledge base.

An improvement of internal processes are expected to be positively related to turnover growth

Usually strategic efforts into the improvement of internal processes are expected to be positively related to turnover growth. Indeed, codification of knowledge, cooperation with partner firms, and the provision of training to employees are found to be directly related to growth (Folkeringa et al. 2004). Having higher-quality human capital may also increase the chances to higher growth and survival. On the other hand, stochastic shocks related to, for example, demand and production costs, may have a negative effect on output.

The results of Folkeringa et al. (2004) indicate that attention to the improvement of internal processes leads to a higher turnover growth for small firms. Examples of such internal processes are reorganizations, routine schemes of products, or the human-research policy towards the selection of innovative personnel. A more efficient innovation process, that is the transition from innovation input into innovation output, is presumably associated with improvements in internal processes. This improved efficiency may have a significant positive effect on turnover growth.

Structural engagement in innovation: constant renewal in strategy

Firms that incorporate constant renewal in their strategy are engaged in innovation on a structural basis. This involves gradual improvements in products or production processes, which may have a negative effect on sales in the short run. According to Folkeringa et al. (2004) this indicates that micro firms are often dependent on the turnover of a small number of products or product categories. If these are still under development or improvement, total sales will be lower in the short and medium run, because a small firm has to trade in marketing and sales activities for these development efforts (see Gifford 1998).

Overall, strategic renewal measures are expected to have a positive influence on firm performance. However, Folkeringa et al. (2004) finds that the coefficient of constant renewal is significantly negative for micro firms.

Negative short-run effects on sales growth can be expected; positive returns in the longer run

One further notable finding of Folkeringa et al. (2004) is that the ownership of patents negatively impacts on small firm performance, particularly for the smallest firms. Artz and Norman (2001) found a similar negative effect of holding patents on sales growth (while not differentiating between size classes). Many innovative firms are in a unique position in the market and as a result of this they may price their product at a premium. This premium increases the profit margin, but as the selling price is higher, consumers turn to substitute products. This in turn has a negative impact on sales growth. On average, positive returns on patents are expected to be visible in the longer run.

The use of external network and market research are found to be positively related to turnover growth

According to Folkeringa et al. (2004), the use of external networks has a significant positive effect on turnover growth for small firms. This network may include universities, competitors, partners, suppliers and/or advisors. Firms that make use of such networks are able to exchange knowledge on the product level, but also information on market structure, trends, and developments could be shared. This raises the level of innovation input (information being one of the inputs).

Market research is found to be an active external network for knowledge acquisition and strategic efforts into the improvement of internal processes are positively related to turnover growth. Market research is an important tool for SMEs to explore consumer wants and to take these into account in product development from a producer perspective. A firm can use market research to investigate the possible demand for a new or improved product or service. The results of Folkeringa et al. (2004) emphasize the importance of both knowledge absorption and knowledge creation to the success of innovative efforts in small firms. They also establish that the impact of the various measures varies with firm size. According to the regression results, systematic firm-size effects occur. This, in turn, indicates that small innovative firms actually have to grow in order to survive. As regards size-class effects, there is no significant difference between small and medium-sized firms, though.

For the middle size-class, firms that have produced new products and/or services have a significant lower employment growth than firms that have not (at the 10% level). When innovation activities have resulted in new products or services, the market introduction follows. This may suggest that for small firms, introduction costs are relatively high, inhibiting employment growth in the short-run. Resources are allocated for the market introduction, leaving little room for hiring new personnel. Exchanging knowledge by means of external networks has a positive effect on employment growth for the middle class of small firms. Similar arguments apply for firms that cooperate with other firms. The effect of lagged turnover growth is significantly positive. When turnover grows, there is more room and need to hire new employees. For employment growth, there are firm-size effects of codification of knowledge and cooperation with other firms.

Knowledge exchange is critical for small firms

According to the findings of Folkeringa et al. (2004) market research and the use of external networks for knowledge exchange were associated with higher turnover growth. In addition, a positive effect of the improvement of internal processes was found, indicating that process innovation created higher turnover growth. These effects were in line with the hypotheses. The direct effects of new products and services on turnover growth were limited, as were the involvement and training of employees and the cooperation with other firms, while knowledge creation and diffusion effects were dominant. Following the argumentation of Folkeringa et al., this does not mean that the involvement and training of employees and cooperation with other firms are not important in the process of strategic renewal, or in creating and adopting knowledge. The direct effects of the knowledge generation efforts are simply more important for turnover growth. For employment growth, firms that used external networks for knowledge exchange and firms that cooperate with other firms experienced more growth than firms that did not. Explicit innovation intention had a particularly strong impact on employment growth for micro firms.

Larger firms are more likely to bring new products or services on the market and to employ people for renewal activities compared to micro firms. This indicates that small firms first have to overcome particular "thresholds" in order to be innovative. The most obvious thresholds in this respect are financial risks and capital restrictions. For small firms in particular, the knowledge exchange is critical in the success of strategic renewal and innovator efforts. Based on the study of Folkeringa et al. (2004) one can expect knowledge management to be of critical importance for performance.

Strategic renewal and innovation efforts – small business economics

Studies of small business economics do not consistently show the positive effect of efforts in renewal and innovation on firm performance (e.g. turnover and employment growth). One reason for this lies in the relatively long period that is typically needed for strategic renewal and innovation activities to contribute to performance. In addition, a reversed causality problem may arise as a direct effect of firm performance on further renewal and innovation efforts. Tackling these reversed causality problems requires typically panel data (see also, for instance, Cainelli et al. 2003). In the panel data analysis, we can also control for the business cycle effects. In fact, given the differences in organization, structure, and behaviour of firms of various sizes, different effects of particular strategic renewal and innovation efforts can be anticipated (both in timing and strength of the effects).

Also the concept of size is ambiguous (Saemundsson 2003). Assets, sales, and the number of employees are commonly used measures of firm size, even if they represent fundamentally different concepts (Weinzimmer et al. 1998). Sales relates to “organizational inputs and outputs” reflecting the level of activity in the organization. Studies of early growth typically concentrate on sales. As Saemundsson points out, it is important to note that corporate growth is conceptually different from the concept of economic performance of a corporation. Economic performance is related to returns on capital invested in the firm, and growth is neither a necessary, nor a sufficient, condition for high return. In entrepreneurship research, firm growth is nevertheless often used as a measure of firm performance. The rationale is that traditional measures of performance, such as market value, return on investment, or profits, do not apply for new ventures in their early phase (Chandler and Baucus 1996).

In the economic literature, employment is perhaps the most accepted method of measuring growth. Another method of measuring growth is the performance in the marketplace. Sales, by value or volume, are regularly used to assess growth levels, as is market share on occasions. Similarly, sales volume may increase but market share decrease; sales value may expand but volume can contract. Merz et al. (1994) contended that entrepreneurship on a continued basis might be best measured by combining two components of revenue change – average annual sales growth rate and sales variances over some time period. In labour market economics, it is a common practice that employment is determined by production, instead of the other way around (e.g. Lever 1996; Van Stel 1999).

Table 5. Determinants of corporate growth, empirical findings and expectations.

Corporate growth

Corporate growth rates are idiosyncratic. Corporate growth is history dependent and every firm seems to have its own history. Very few firms produce major innovations or patents on a regular basis. This means that growth spurts experienced by firms are unpredictable. The characteristics of growth rates may be due to the unpredictable and stochastic nature of innovation success. The relationship between innovation and productivity growth is better reasoned than the relationship between innovation and corporate growth.

Stylized facts which, at best, are partial

Advertising expenditure, the demand growth of an industry, and also industry concentration are observed to have a positive influence on firm growth rates. However, their explanatory power is usually observed to be remarkably weak.

There is a close relation between growth dynamics within a sector and firms' growth rates. It is expected that strong demand for the firm's products will enhance its growth. Furthermore, agglomeration effects can produce positive externalities that affect the growth of firms. Improved efficiency may also have a significant positive effect on turnover growth. An increase in market share and market expansion may result in an increase in sales growth and in labour demand. Market share, in its part, may respond to increases in labour productivity through relative prices or the quality of product. There is also evidence that growth strategy matters. Stochastic shocks related to e.g. demand and production costs may have a negative effect on output.

In many sectors, new technology reduces the necessity of scale economics to arrive at competitive advantages. However, positive returns on patents are expected to be visible in the longer run rather than in the short run. The use of market research and external networks are observed to have a significant positive effect on turnover growth for small firms. Also process innovation creates higher turnover growth. The direct effects of new products and services on turnover growth are, however, limited.

A major difficulty in observing the effect of innovation on growth is that it may take a firm a long time to convert increases in economically valuable knowledge into economic performance. The effects of innovation on production are usually revealed with a considerable lag.

3.6 Role of innovation in productivity, growth and market shares

Innovation as a main driver of firm performance

Schumpeter (1942) and Nelson and Winter (1982), among others, have stressed that innovation is the key to economic growth. However, before panel data sets, there was little empirical evidence of the link between the innovativeness of firms and their performance. Baldwin et al. (1994) demonstrate that in small and medium-sized Canadian firms, a measure of success that is based on growth, profitability and productivity is strongly related to the emphasis that firms place on innovation. Later on, Baldwin (1998) uses a sample of entrants to show that growth in new firms depends upon whether the firm innovates.

More-innovative firms place a greater emphasis on marketing, finance, production, and human resource competencies than less-innovative firms

According to the findings of Baldwin and Sabourin (1995), the production process between large and small firms is extremely different since technology use is not the same in these firms. The differences between large and small firms that are observed come from a host of factors that changes as firms grow. They also argue that few economic studies consider many firm-specific competencies, except for R&D, as contributing factors to innovation. Yet, over time, firms build up a set of competencies that are crucial for their overall growth and development. Baldwin and Johnson (1995) find that more-innovative firms place a greater emphasis on marketing, finance, production, and human resource competencies than less-innovative firms.

Market structure as endogenous outcome of growth

The research has also recognized that market structure, rather than simply being an exogenous determinant of innovation, is more likely an endogenous outcome of the dynamic growth of innovating firms under favourable appropriability conditions (Levin and Reiss 1984, 1988; Cohen and Levinthal 1989). Firms that can effectively protect their innovations – through the use of patents, trade secrets or other forms of intellectual property rights (IPRs) are expected to have a greater likelihood of being innovative. In turn firms that innovate are more likely to use patents. This means endogeneity between IPRs and innovativeness.

Firms engaged in R&D are more likely to innovate

Baldwin and Johnson (1995) discover that R&D activity and firm size have the greatest impact on innovation regardless of the model used. Firms engaged in R&D are more likely to innovate and technological opportunity is a statistically significant determinant of innovation. Firms in industries relying on science-based research are more likely to be innovative. The importance of appropriability conditions on innovation will, however, be incorrectly represented if endogeneity is not taken into account.

Continuous R&D, technology competencies and past innovation activities has a bearing on innovation outcomes

There is strong evidence on the connection between the growth in new firms and innovation. There is, however, less evidence of the factors of whether a firm adopts an innovation policy. The study of Baldwin and Gu (2004) examines the determinants of innovation and the role of innovation in productivity, growth, shifts in market share and survival in the Canadian manufacturing sector. They find strong evidence that labour productivity growth is faster and survival rates higher after the introduction of a process innovation. Process innovation is also linked to gain in market shares through its effect on productivity growth. Product innovation appears to have little impact on plant performance. R&D investment, competencies and past innovation activities are shown to be the three main factors affecting innovation outcomes of Canadian manufacturing firms. Being a performer of continuous R&D is closely related to innovation of most types. The second factor affecting innovation outcomes is technology competencies of firms. The study finds no evidence that the emphasis on marketing, production and human resources is related to innovation. The third factor affecting innovation outcomes is past innovation activities. The use of patents and trade secrets which is associated with past innovation is a strong predictor of being an innovator.

Different types of innovators are at different phases of the product life cycle

In the study of Baldwin and Gu (2004) firm size is found to be more closely related to process innovation than to product innovation. In addition, foreign-controlled firms have innovation rates that are about 10 percentage points higher than their domestic counterparts have. The higher innovation rates of foreign-controlled plants are a result of their larger size, higher export participation rates, technology competencies, and past innovation activities. After controlling for these firm characteristics, the nationality of a firm is not significantly related to innovation. This suggests that these different types of innovators are at different phases of the product life cycle. Product innovations dominate the early stages of the life cycle. In a later stage, process innovation is more important than product innovation for labour productivity growth. The result that process innovation matters for productivity growth confirms findings from many other studies (e.g. Baldwin and Sabourin, 1995). Technology use is related to faster productivity growth.

In the early stages, innovation is not expected to be closely related to productivity gain

In the study of Baldwin and Gu (2004), large firms are more likely process innovators and process innovation is more likely associated with productivity growth. According to Baldwin et al. the focus of firms varies over the life cycle and so does their success. Early in the life cycle, entry and exit are high, and firms tend to focus on developing new products. Especially after the market shakeout firms become to get larger as they focus more on reducing production costs and competing more on price in a market where products are distinguished less on the basis of product characteristics and more on price. In the early stages of the life cycle, innovation is not expected to be closely related to productivity gain. Baldwin et al. finds that it is not surprising that process innovation affects productivity growth while product innovation is less likely to do so. Firms that are engaging in product innovation are more likely in the early stage of their life cycles where productivity growth is not high. Small firms are at a different stage in their life cycle compared to large firms. The same process is at work with regard to changes in market share. Here too, large plants are likely to lose market share because of the forces of competition. And here too, innovations serve, via productivity improvements, to reduce the tendency to lose market share. This tendency is more pressing for large firms than for small firms.

Competition tends to stimulate cost-cutting improvements

Product innovations involve the introduction of a new product or the increase in quality of an existing product, while process innovations tend to reduce production costs. Cohen and Klepper (1996b) find that the type of innovation produced depends on size and appropriability conditions. According to their results, larger firms have a greater incentive for process innovations than do smaller ones, while smaller firms are more likely to concentrate their efforts on product than process innovations. Competition tends to stimulate cost-cutting improvements associated with innovation. It has a minor effect on the quality changes associated with innovation in product markets.

Faster growing entrants are twice as likely to report an innovation as slower growing firms

A set of previous studies for Canada have reported that the innovative capabilities of individual firms are related to measures of performance. Baldwin (1996) and Baldwin and Johnson (1998) find that while firms need to do many things better in order to succeed, innovation is the one factor that appears to discriminate best between the more successful and less successful firms. Baldwin (1996) and Baldwin et al. (1994) study growing small and medium-sized firms in the 1980s and find that the key characteristic that distinguishes the more successful firms from the less successful firms is the degree of innovation taking place in a firm. Baldwin and Johnson (1998, 1999) use a survey of entrants and report that in new firms, growth in output is closely related to innovation. They found that faster growing entrants are twice as likely to report an innovation, and are more likely to invest in R&D and technology than slower growing firms.

The emphasis on human resources was not found to be significantly related to the probability of innovation

Of the firm-strategy variables, Baldwin and Gu (2004) emphasize the technology and marketing strategy and both of these are observed to be positively related to innovation. Firms that place more emphasis on their technology strategy are more likely to innovate. On the other hand, as pointed out by Mowery and

Rosenberg (1989), among others, R&D is not the only important input into the innovation process. The results got by Baldwin and Gu suggest that appropriability stimulates innovation. But it is not patents that matter so much as trade secrets and other strategies that allow a firm to expropriate the fruits of its investments in intellectual capital. In industries where trade secrets are seen to be effective, the probability that innovation occurs is higher. Patent use is, however, strongly related to whether a firm is an innovator. Both innovation and patent use are related to size. In addition, patent use but not innovation is related to the nationality of the firm. Foreign-owned firms are much more likely to protect their innovation with patents. The emphasis on human resources was not found by Baldwin et al. to be significantly related to the probability of innovation.

Scientific environment is important for the creation of novel innovations

Baldwin and Johnson (1998) also explored differences between innovators and non-innovators. They estimated a probit regression using novelty of innovation as the binary dependent variable. They found that size is more important in the case of world-firsts than for Canada-firsts. Scale and scope economies are, therefore, closely related to novelty. While competition is important for all innovators taken together, it does not make a difference between the world-first and all other innovations and between Canada-first and other innovations. Scientific environment is more important for the creation of novel innovations. Firms operating in industries that rely more on science-based research are more likely to produce world-first innovations than other types of innovations. Patent use is important for distinguishing the more novel from the less novel, but it differentiates primarily between Canada-first innovations and imitative other innovations only. According to Baldwin and Johnson the causal relationship is much stronger going from innovation to the decision to use patents than from the use of patents to innovation. This extends the findings, based on survey evidence (Mansfield 1990; Levin and Reiss 1988; Cohen 1996), that patents are not seen by firms to be a very efficacious means of protecting innovations.

Developing innovative capabilities is often a prerequisite for innovation

While developing an R&D emphasis is important, developing capabilities in a number of different areas is also generally a prerequisite for innovation. In particular, firms which give a higher emphasis to technological capabilities and to marketing competencies are more likely to be innovators. According to Baldwin

(1998), this is particularly important when it comes to innovations that involve both changes in products and processes. In the study of Baldwin (1998), the emphasis on human resources was not seen to be important and was not included in the analysis – a finding that is contrary to results found for new firms. The emphasis on production strategies was also seen not to be related to the probability that a firm is innovative. Size was found to be positively related to innovation, although the relationship is not monotonic. The largest size class (i.e. over 500 employees) differs from the others in that they are the most innovative. This relationship is more important for process innovations, thereby confirming the finding of Cohen and Klepper (1996a, 1996b). In contrast, the fruits of a product innovation are more easily realized by selling it to others.

R&D is more important for product innovations than for process innovations

Consistent with the previous studies on R&D and innovation, the results of Baldwin (1998) show that R&D is an important determinant of innovation. The importance of R&D for innovation, however, differs across types of innovations. R&D is more important for product innovations than for process innovations. Baldwin also finds that dividing innovations into process only and product only innovations increases the difference in the effect of the variable. In addition, firms that place more emphasis on their technology strategy are more innovative. In contrast, the emphasis on marketing, production and human resources is not significantly related to innovation. The results also show that firms that developed innovations in the past are more likely to innovate.

It is difficult to measure the amount of innovative sales in large companies

Baldwin et al. (2004) found, that large firms tend to have larger process innovation rates (innovation intensities) than smaller firms. However, no evidence that past growth is related to innovation was found. The results of Baldwin et al. show that within the group of innovators, R&D and the past productivity growth is not related to innovation rates. Furthermore, firms with increasing market shares tend to introduce more innovations than firms with declining market shares. They also found that innovation rates within the innovator group are not monotonically related to productivity growth. In addition, it is process not product innovation that is more closely related to productivity growth. Baldwin et al. also point to the difficulty to measure the precise amount of sales in a large company that come from a product innovation − especially if the innovation is incremental and is an add-on to an existing product.

Process and product innovations have different effects on productivity

Baldwin et al. (2004) find that product and process innovations have different effects on productivity growth. Process innovation is a strong and significant determinant of productivity growth. In contrast, product innovation was not related to productivity growth. This finding on the different impact of process and product innovations for Canada is consistent with the findings of Criscuolo and Haskel (2003) for the U.K. and Leiponen (2000b) for Finland, while Leiponen (2002) finds that product innovation is negatively related to productivity growth for Finland. Also Griliches (1998) finds that an increase in product R&D share of total R&D investment is associated with a lower rate of productivity growth. Griliches suggests two reasons for this negative relationship. First, new products tend to be disruptive to established production processes and productivity growth is likely to suffer as a result. Second, where new products are an important aspect of competition, the business may adopt a relatively flexible process technology and some sacrifice in productivity in the flexibility is likely to result.

There is a substantial regression-to-the-mean effect in productivity

Furthermore, Baldwin et al. (2004) find that world-first innovations have a much stronger effect on productivity growth, and that even though technological development is important for innovation, it has no additional effect on productivity growth. Instead the results indicate that there is a substantial regression-to-the-mean effect in productivity. The most productive plants tend to be the ones that are more innovative. But the most productive plants also tend to regress to the mean. The innovation rates of innovating firms are not related to the productivity growth of their plants.

Innovation is not related to market-share growth except for novel innovation

Most of the studies by Baldwin et al. (2004) on innovation and productivity growth have used a sample of surviving plants. Due to data constraints, these studies relate innovation to plant growth in the same period, and found out that innovation is not related to market-share growth except for the world-first innovation type. Changes in market share is here modelled as a function of productivity, relative productivity growth, plant and firm characteristics and the opening period market share to account for regression-to-the-mean. Innovation and particularly process innovation is positively related to productivity growth, and productivity growth is related to market-share growth, but there is no statistically significant effect of innovation on growth in market share. Baldwin et al., therefore, suggest that the type of R&D that serves to permit product adaptation rather than results in a discovery of brand new products is the most critical to market-share growth.

Baldwin et al. also examined the link between innovation rates and market-share growth and found that innovation rates are not related to market-share growth within the group of innovators. World-first innovation is related to grow in market share, while other types of innovation are not. They also found that being a performer of continuous R&D is closely related to innovation of most types, though it is more important for the most novel than the least novel innovations. Having technological competencies is also important to the innovation process. Other competencies related to marketing and human resources are not found to be closely associated with a successful innovation. Past innovators are more likely to be future innovators thus, building innovation capability matters. But past growth is not particularly related to whether major innovations are reported for the survey period.

In the early stages of a firm, innovation is not closely related to productivity gain

Although innovation does not directly affect changes in market share, it does increase market share indirectly through its impact on labour productivity, because market share responds to increases in labour productivity. The results stress the importance of process innovation to productivity growth. Process innovation leads to gains in productivity and changes in productivity are then translated into gains in market share. According to Baldwin et al. (2004) we can see how innovation fits into a larger pattern of firm growth and decline. Firms, products and industries pass through life cycles. Their focus varies over the life cycle and so does their success. Early in the life cycle, entry and exit are high. Firms tend to focus on developing new products. In the early stages of the life cycle, innovation is not expected to be closely related to productivity gain. Indeed, in the early stages of a firm, productivity gains may not be very important.

Baldwin and Dhaliwal (2001) report that firms that are growing their labour force are often not growing their productivity, and firms that are engaging in product innovation are likely to be in the early stage of their life cycles where productivity growth is not high. The finding that the incidence of product innovation is larger in plants that are exporters suggests that product innovation in the early 1990s was particularly important in export markets.

Table 6. Determinants of corporate growth in new firms, empirical findings and expectations.

There is strong evidence on the connection between the growth in new firms and innovation. Innovators are likely to grow more than non-innovators. The influence of specific innovations on sales growth is nonetheless short-lived. Sales growth can be taken as a crude approximation of productivity growth, especially in services. Labour productivity growth is faster and survival rates higher after the introduction of a process innovation. Competition has only a minor effect on the quality changes associated with innovation in product markets. On early stages of a firm, product innovation increases performance but then process innovation takes over. Product innovations dominate the early stages of the life cycle. In a later stage, process innovation is more important than product innovation for labour productivity growth. In the early stages of the life cycle, innovation is not expected to be closely related to productivity gain. Product innovation can even be negatively related to productivity growth. R&D is more important for product innovations than for process innovations. Small firms are at a different stage in their life cycle compared to large firms. The production process between large and small firms is extremely different since technology use is not the same in these firms. Technology and marketing strategies are observed to be positively related to innovation. Human resources are important especially for new innovators.

3.7 Knowledge production function framework

R&D capital stock as a factor of production

Griliches (1979) was the first to introduce R&D capital stock as a factor of production into the residual computation framework pioneered by Solow (1957). In this approach, R&D activities add to the existing stock of accumulated knowledge of firms, leading to productivity growth through product and process innovation. Romer's (1990) growth model predicts a link between R&D activity and productivity growth, and Cohen and Levinthal (1989) point to the importance that R&D activity can have in absorbing technology produced in other firms (Knell and Rojec 2007).

Innovation Surveys have just quite recently extended the measurement of the innovativeness

The direct and indirect effects of R&D and innovation activities have been studied by using firm-level data with information on firm's R&D and patenting activities. The firm-level Community Innovation Surveys (CIS) have just quite recently extended the measurement of the innovativeness. The availability of new innovation output indicators has shifted much of the attention away from the single-equation estimation of the determinants of traditional input measures such as R&D intensities to the single-equation estimation of the determinants of innovation output, on the other hand, and to the simultaneous equation system estimation of a joint dependence of both measures of innovativeness on firm specific innovation characteristics, on the other hand.

Relationship between innovativeness and firm performance

Conventionally the relationship between innovativeness and firm performance has been studied by using the production function framework. The original model based on Pakes and Grilliches (1984) focused on the relationship between R&D activity and productivity growth. Pakes and Griliches also introduced the knowledge production function concept which relates R&D activity to patenting or other “inventive output” or innovation output measure. In the underlying theory the success of a particular research project depends stochastically on the level of current and past R&D investments. In this model, innovation inputs included only patents and R&D activity, and R&D expenditures were assumed to be exogenous.

Relationship between R&D, patenting and productivity

There are several reviews of the early literature that measure the relationship between R&D and productivity at economy, sectoral and firm levels, including Nadiri (1991), Griliches (1992), Mairesse and Mohnen (1995), Cincera (1998), Kleinknecht and Mohnen (2002) and Wieser (2005). The most notable contribution is Pakes and Griliches (1984) who develop a variant of this framework in which changes in knowledge capital are unobservable, which allows for the inclusion of several interrelated innovation inputs. They studied the relationship between R&D and patenting in the 1968−1975 period for a large number of firms and found that the sum of the contemporaneous and lagged effects is positive and significant. They also point out that patents are a flawed measure of innovation output; particularly since not all innovations are patented. More recently, Jaffe and Trajtenberg (2002) suggest that patent filings can be an important source of technology spillovers and support for Romer's (1990) model.

Determinants of R&D inputs and innovation incidence

Using the first wave of the Dutch CIS, Brouwer and Kleinknecht (1996) included the sectoral demand growth of a firm in the equation for R&D inputs in order to capture the feedback mechanism. Their results show a significant positive feedback effect from sectoral sales growth on the growth rate of R&D labour inputs. In Cosh et al. (1999), the impact of past performance on the probability of having implemented product or process innovation in 1992−1995 was modelled for SMEs in the UK. Cosh et al. included past employment growth at the industry level and the realization of product or process innovation in the firm in 1986−1991 as explanatory variables in the probit regression.

Joint determination of innovation input and the organization of the innovation process

Brouwer and Kleinknecht (1996) used a firm's past performance as a determinant of the share of innovative products in a firm's total sales. In these studies feedback mechanisms were investigated by implementing them on the last stage of innovation process, rather than by examining the impact of own performance on own inputs into the innovation process. According to Klomp and van Leeuwen (2001), exploring the latter seems more natural in light of a conceptual system which places the joint determination of innovation input and the organization of the innovation process (for instance the "make or co-operate or buy" decision with respect to R&D or the use of technological opportunities available from different information sources) at its beginning and overall economic performance at its end.

Joint determination of innovation output and firm performance

Following the argumentation of Klomp and van Leeuwen (2001), formal models of innovation stress the links between the input, the throughput and the output stage of the innovation process and the links between the innovation process and economic activity. There are, however, different routes to the empirical testing of the many dimensions underlying the relationship between innovation and the overall economic performance. With the innovation model of Kline and Rosenberg (1986) as a frame of reference, Klomp and van Leeuwen attempted to estimate simultaneously the determinants of the innovation inputs, the factors determining the share of innovative sales in total sales and the contribution of innovation output to total sales and employment growth at the firm level.

Innovation co-operation and innovation sources as throughput in innovation process

In the empirical model of Klomp and van Leeuwen (2001), the input was measured by intramural R&D expenditures, the throughput by extramural R&D expenditures, innovation co-operation and sources of information for innovation projects, and the innovation output by the share of new or improved products in total sales. They found that innovation output contributes to a firm's total sales growth and thus affects its overall economic performance which in turn is assumed to affect the inputs into innovation as measured by the level of innovation expenditures. In addition, it was assumed that a firm's overall sales growth may affect the level of innovation output directly. In a broad view, the model links a firm's own innovation performance to the exogenously given market potentials and to the availability of technological opportunities.

Sector-specific market potentials and technological opportunities

Klomp and van Leeuwen (2001) used sectoral dummy variables to take account of the sector-specific market potentials open to a firm. They used two factors to represent the use of technological opportunities: technological information sourced from science and technological information sourced from other firms such as suppliers or customers or competitors. The technological environment of a firm may also affect its organizational arrangements. Therefore, in their empirical model Klomp and van Leeuwen used proxy variables which refer to organizational aspects in order to take account of the notion that a firm may absorb knowledge from the environment via supplier and producer-customer interactions (information sources), or may build up and maintain its own knowledge base via R&D investment and R&D co-operation. They also use dummy variables to indicate the presence of permanent R&D facilities and the emergence of innovation in partnerships with other firms. One may expect a cost-push effect on innovation expenditure of the technological opportunity factor "science" due to the absorptive capacity argument.

R&D and non-R&D co-operation

A co-operation between R&D firms and research institutes and universities requires relatively high internal research skills in order to assimilate the fruits of the co-operation and to internalize and commercialize the knowledge created during the co-operation (ibid). On the other hand, a co-operation with suppliers, customers and competitors is expected to have lower research competence requirements, a smaller impact on the organization of firms, and thus a lower cost-push effect on innovation expenditure than the technological opportunity factor "science". According to Klomp and van Leeuwen (2001) one can imagine that non-R&D co-operation affects innovation throughput more directly than R&D co-operation and consequently may have a larger effect on the level of innovation output than the technological opportunity factor "science".

Persistence in both innovative and economic performance; a more structural approach is needed

It is often conjectured, that there is persistence in both innovation and economic performance, and that current innovation performance is a positive function of past overall economic performance. This hypothesis has been tested occasionally by using total sales growth as a determinant of the share of innovative output in total sales (like in Brouwer and Kleinknecht 1996). As pointed out by Klomp and van Leeuwen (2001) another problem which calls for a more structural approach to empirical modelling is the role of technological opportunities. The use of technological opportunities may affect the level of innovation expenditures (technology push) and thus the inputs into innovation but the same opportunities may also affect the level of innovation output directly. Klomp and van Leeuwen (2001) therefore conclude that given the market potentials and the technological opportunities open to the firm, the use of technological opportunities may affect both the level of innovation expenditures, as well as the innovation throughput directly. In their model, innovation success is expected to depend either on investment in innovation or on a more informal non-R&D driven co-operation with other firms (e.g. non-R&D driven collaboration in innovation). Investment in innovation can take the form of building up or maintaining own R&D capital stock or it can be based on the exploitation of technological opportunities via R&D co-operation.

Innovating firms are performing better than non-innovating firms as regards to total sales growth

Klomp and van Leeuwen (2001) matched the CIS and the production data in order to compare the performance of innovating and non-innovating firms. They made a comparison for two performance measures: the average growth rates in 1994−1996 for total sales and employment of respectively innovating firms, non-innovating firms and the full sample, and concluded that innovating firms are performing better than non-innovating firms as regards to total sales growth but that the differences are less pronounced for the growth rates of employment. They also report that the main message from the distributions is the overwhelming heterogeneity in firm performance for the innovating as well as for the non-innovating firms. Firms' growth rates vary significantly among the different industries. Consequently, it is expected that technological innovation will not be able to explain all observable heterogeneity.

Innovation output and growth performance were assumed to be jointly endogenous

Klomp and van Leeuwen (2001) used the data on innovating firms, and aimed to estimate the contribution of innovation to growth in sales and employment and to investigate the importance of firm-specific innovation characteristics and the existence of persistent relation between innovation and overall economic performance. Their basic assumption was that a firm's total sales and employment growth depends on its innovation output as measured by the share of new or improved products in total sales. This measure refers to the level of innovative output. Consequently, they assumed that a firm's innovation output and its total sales growth and employment growth are jointly endogenous. They also considered that the inputs into innovation are endogenous because the variables which measure the resources devoted to innovation refer to the same year as well. They included the log-odds ratio as an explanatory variable in the equations for total sales and employment growth.

Technological opportunities and permanent R&D facilities most significant

Klomp and van Leeuwen (2001) used dummy variables to indicate the presence of permanent R&D facilities and innovation in partnerships in order to manifest a firm‘s organizational arrangements regarding the innovation process. They included the average growth rate for total sales in order to capture the feedback effect from general firm performance. They found that the explanatory variables that are most significant are the variables that refer to the use of technological opportunities and the presence of permanent R&D facilities. They also found that innovation expenditure intensities decrease with size as well as with age, indicating that younger firms spend relatively more resources to innovation than older firms. They report that the estimates of the coefficients of the variable “sales growth” are significantly negative contradicting the Schmookler’s demand pull hypothesis of a positive feedback effect from own past performance to innovativeness (see Schmookler 1966). Schmookler’s hypothesis is, however, confirmed in the significant positive feedback effect from firm-level sales growth to the level of innovation expenditure intensity.

A significant positive effect of the level of innovation output on sales growth was observed

The insignificance of the demand-pull dummy variable in the model can be explained by the fact that only relatively few firms rated demand factors as an unimportant objective for implementing product or process innovation. The empirical facts that – on average – business services firms are smaller, younger, are performing R&D on a permanent basis more seldom and also showed a higher growth rate for their total sales as compared to manufacturing firms is confirmed in the probit estimates of the generalized tobit model (censored regression model). The use of technological opportunities offered by customers, suppliers and competitors has a larger effect on the level of innovation output than the use of these opportunities offered by science. A significant positive effect of the level of innovation output on sales growth was observed, but not for employment growth. In the system estimation, Klomp and van Leeuwen (2001) use three different specifications. The contribution of innovative sales to growth in total sales is significantly positive for all three, although the estimates differ remarkably between the specification including only firms with innovative sales and the specification with innovative firms as well as non-innovative firms.

Exploring the channels through which R&D activity influences innovation and productivity: the CDM model

In an attempt to make R&D investment endogenous in the knowledge production function, Crépon, Duguet and Mairesse (1998) expanded this framework to a four-equation recursive model, the so called CDM model. The basic idea of CDM model is to explore the channels through which R&D activity influences innovation and productivity as well as the R&D decision. First, firms' size, industry, diversification, market share, as well as demand pull and technology push affect their R&D activities, then R&D activities adds to knowledge capital and knowledge capital generates innovation which in its turn affects productivity. In the CDM model, it is assumed that firms use enhanced Cobb-Douglas technology with constant returns to scale and use also knowledge inputs in addition to labour and capital inputs. The model combines a knowledge production function relating R&D activity to patenting or innovative activities, with economic performance as measured by labour productivity. It contains a system of three simultaneous equations where R&D activity and other factors generate new knowledge, which then propels innovation (output) and finally productivity growth.

The original model developed by Crépon et al. (1998)

The model developed by Crépon et al. (1998) is a 3 stage model, with 4 equations. In the first stage they use a generalized tobit model to explain the firm's decision whether to engage in R&D activities or not and the decision on the amount of R&D. In the second stage they estimate the knowledge production function where innovation output depends on R&D investment. In the third stage they estimate the innovation output and productivity link using an augmented Cobb-Douglas production function. They estimate this as a recursive system using the method of asymptotic least squares (ALS, minimum distance estimator) and exclusion restrictions for identification. It is a system of simultaneous equations with limited dependent variables, i.e. a 2-stage method which needs exclusion restrictions. In stage 1, the reduced form equations of the model are estimated consistently. In stage 2, a structural equation is estimated by minimizing a weighted distance between the vector of reduced form parameters estimated in stage 1 and the parameters predicted by the model from the identifying constraints. Crépon et al. find evidence for a positive effect on R&D activity and innovation output measured by patent numbers, as well as a positive and significant effect on value-added per employee of French firms.

Revised CDM model: instead of constructing knowledge capital from R&D, knowledge is measured by innovation output indicators

In a revised CDM model, R&D affects knowledge and knowledge affects productivity, but instead of constructing knowledge capital from R&D, knowledge is measured by innovation output indicators (see Kremp et al. 2006). A revised CDM model includes four relationships: (i–ii) the probability of engaging in innovative activities (R&D or innovation selection) and the size of innovative activities (R&D or innovation intensity), (iii) the knowledge production function KPF relating innovation input to economically valuable innovation output measures and (iv) the productivity equation relating innovation output to productivity growth. Firms first decide whether to engage in innovation, then they choose how much to invest in innovation. Innovation effort is used with other inputs to produce new knowledge or innovations in the KPF. For innovation selection probit or logit models are used, tobit or ordered probit models are used for the share of innovative sales, Poisson or negative binomial models for patent applications.

Also revised models based on the selection equation, i.e. on the decision equation to invest or not, innovation output functions and the selection of the appropriation strategy (patents, trademarks) have been proposed.

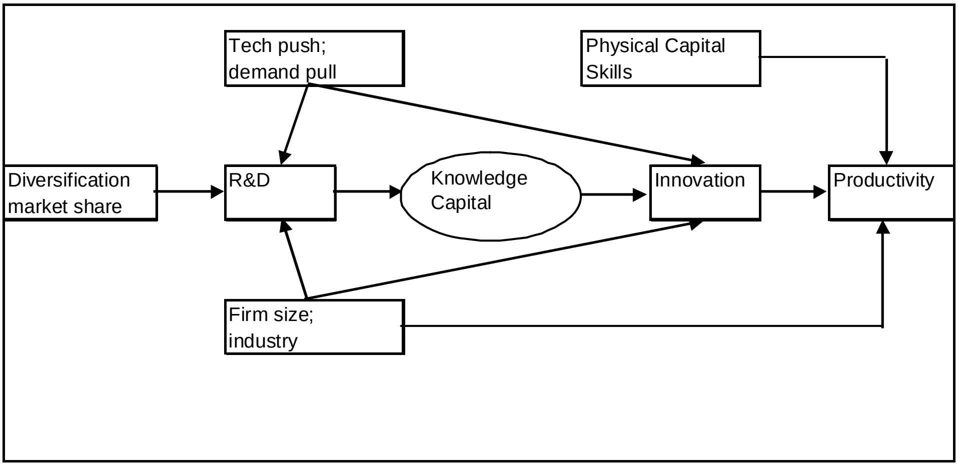

Figure 3. The original CDM model (Mairesse 2006; Crepon et al. 1998).

Results on the relationship between innovation and productivity growth are mixed

These studies focus both on the determinants of innovation and on the connection between innovation and performance. In the first case, they find that R&D is closely related to innovation. Crépon et al. (1998) report that the share of sales from product innovation is positively related to R&D capital in French manufacturing firms. Van Leeuwen (2002) finds similar evidence for Netherlands, as do Criscuolo and Haskel (2003) for the UK, and Lööf and Heshmati (2002) for Sweden. Similar evidence is reported also for Canada (Baldwin et al. 2000). Crépon et al. also find that the share of sales accounted for by innovative products is positively related to the level of productivity across French manufacturing firms. Lööf and Heshmati (2002) find a strong relationship between the share of sales from innovations and value added per worker for both manufacturing and services firms. The results on the relationship between innovation and productivity growth are, however, mixed. Lööf and Heshmati find a positive relationship between innovations new to the market and labour productivity growth across Swedish manufacturing firms. In contrast, van Leeuwen (2002) finds that process innovation does not appear to be linked to productivity growth while product innovation does for Dutch manufacturing firms. By using a sample of UK manufacturing firms, Criscuolo and Haskell (2003) show that process innovation is related to productivity growth while product innovation is not.

Both selection and endogeneity has to be controlled for

The Crépon et al. (1998) model relies on the strong assumption that the four error terms are not correlated. However, in practice it is highly likely that they are correlated. In principle, this problem can be solved by estimating knowledge production function using instrumental variables method (2SLS), and by using predicted innovation expenditure from e.g. a generalised tobit model. In addition, if estimates of KPF are based only on innovative firms, there is also a need to correct for selectivity using Heckman correction term (Mill's ratio). The sample selection bias occurs where the dependent variable is observed only for a restricted, non-random sample. This can happen when the model only includes innovating firms. The sample selection bias suggests the use of the Heckman selection correction model. We, therefore, have to control both for selection and endogeneity.

Some variants and modifications of the CDM model: the Nordic model

After the basic work done by Crépon, Duguet and Mairesse some variants to the CDM model that integrate CIS data with e.g. a panel data of firms have been developed. Recent studies by e.g. Duguet (2000), Mairesse and Mohnen (2001, 2002), Klette and Kortum (2002), Mohnen and Therrien (2003), Janz, Lööf and Peters, (2004), Peters (2008), Lööf and Heshmati (2006), van Leeuwen and Klomp (2006), Hall and Mairesse (2006) and Mohnen (2006) are examples of these variants. In the multi-step approach of Lööf and Heshmati the four equation model is as follows: separately estimate innovation effort equation using probit and then calculate Mill's ratio, separately estimate innovation expenditure equation using tobit model, then estimate innovation output equation including Mill's ratio and predicted innovation expenditure and productivity growth as regressors and estimate this simultaneously with the productivity (growth) equation to allow for feedback effects. In the so called Nordic model the full sample has been used for estimating the selection equation and only innovative firms are used in equations (ii–iv). Equations (iii–iv) are estimated by using 2SLS or 3SLS (instrumental methods). A disadvantage of this method is that different countries require different specifications.

Methods to handle selection and endogeneity

The basic method to handle selection is to include the non-innovative firms in the total sample in a selection equation for estimating a non-selection hazard, or what Heckman (1979) refers to as the inverse of Mill's ratio. If only the innovation sample is used, the firms are not randomly drawn from the larger total sample population, and selection bias may arise. In addition, as pointed by Lööf, it is not easy to establish causality. Innovations are affected by the level of output and by past profits and productivity. For this reason, it is inappropriate to limit the focus only to innovative firms and the method suggested by CDM is basically a panel data model with a selection equation: equation 4 is linked to equation 1. The robustness of the CDM model may be problematic. Reverse causality problems appear because innovation inputs and outputs occur simultaneously in the CIS data (innovation improves productivity, while productivity growth encourages innovation). Identification can be achieved by using simple weighted averages, a two-stage procedure or by finding a suitable instrumental variable, but choosing the wrong instrument can also cause additional problems (Arellano, 2005). To handle endogeneity in a model of sample selection, Lewbel (2005) suggest a flexible estimator which takes the form of either sample weighted averages or GMM or 2SLS. Lewbel estimator stems from a semi-parametric qualitative response model with unknown heteroskedasticity and instrumental variables. Besides the potential heteroskedasticity (e.g. different variances among small and large firms), many of the models above are linear, even though the relationship between innovation and productivity is probably non-linear. Testing for nonlinearity is also testing for heterogeneity, particularly since the returns to R&D activity is heterogeneous across firms.

Innovation output positively and significantly affects firm performance

The paper by Crépon et al. (1988) has influenced a new and rapidly increasing literature on the relationship between innovation output and firm performance. Firm performance variables may include value-added, sales or exports per worker and the growth rate of value-added, sales, profitability or employment, and sales margin, profit before and after depreciation. The main finding of these studies is that, regardless of how performance is measured, innovation output positively and significantly affects firm performance, with the exception of the study by Klomp and van Leeuwen (2001) that finds a negative but insignificant effect of innovation output on employment growth (Hall and Mairesse 2006; Raymond et al. 2006). Pianta (2005), however, points out that empirical studies of the relationship between innovation and employment identify both a positive and a negative effect of the former on the latter. The sign of the relationship depends on the type of the data, the time-period and whether it is at the firm level. Lööf and Heshmati (2006) perform a sensitivity analysis of the different measures of firm performance and find the same pattern of positive and significant effect of innovation output on firm performance.

Micro-aggregated data from seven countries, simultaneity tends to interact with selectivity

Similar results are found in other papers. Mohnen, Mairesse and Dagenais (2006) estimate the relationship between innovation output and firm performance using micro-aggregated data from seven countries (Belgium, Denmark, Ireland, Germany, the Netherlands, Norway and Italy) for 1992. They use a generalized tobit model together with a production accounting framework and include size, industry, ownership type, continuous R&D, cooperative R&D, R&D intensity, proximity to basic research, and perceived competition as independent variables and found that firm productivity correlates positively with higher innovation output, even when correcting for the skill composition of labour and capital intensity, but they also found that simultaneity tends to interact with selectivity, and that both sources of biases must be taken into account together.

Employment effects: compensation and displacement effects

The analysis could also be extended to employment effects by disentangling the different effects of process versus product innovation. Some studies have found that process innovation has a direct displacement effect from increased productivity; and an indirect compensation effect through expansion in demand. Product innovation may have a direct compensation effect through increased demand for the new product and an indirect displacement effect if the production of new products is more efficient. Griffith et al. (2006) estimates a variation of the CDM model for four European countries (France, Germany, Spain, and the UK), using firm-level data from CIS3 carried out in 2000. Griffith et al. used maximum likelihood estimation of the generalized tobit model. This model differentiates between labour displacement effect of process innovation and the compensation effect caused by higher demand. They find that job loss due to process innovation is partly compensated by the displacement effect and that there is no evidence of a displacement effect when there is product innovation, even when old products are no longer produced. Although they find that the results are similar across these four countries, the employment effects are different.

A considerable variation between Finland, Norway and Sweden due to data errors

The paper by Lööf et al. (2002) shows that there is considerable variation between Finland, Norway and Sweden in the early 1990s. They argue that this variation may be due to data errors, the econometric model (3SLS), model specifications, or unobservable country effects. Using CIS data from France in 1993, Duguet (2000) shows that strongly innovative firms are much more likely to improve their total factor productivity than weaker firms, and that the return to innovation increases with the degree of innovation opportunities that firms have. The model also shows that the Solow residual at the industry level is linked to radical innovations at the firm level. Janz et al. (2004) pool observations from the German and Swedish innovation surveys and show that there is a strong link between innovation output and sales per employee in knowledge intensive manufacturing firms independent of the country.

The impact of innovation differs between measures of firm performance; the national samples may not be representative

Using data from the Netherlands in 1997, van Leeuwen and Klomp (2006) show that the impact of innovation differs between measures of firm performance and that additional information on the technological environment of the firm can improve the estimation. Mohnen and Therrien (2003) compared Canada with selected European countries in the late 1990s and found that Canadian firms where more innovative as a hole, but with a lower share of sales from innovative products for its innovative firms. These results led the authors to suggest that the national samples may not be representative and the differences in the questionnaire or perceptions of the questionnaire matter (Criscuolo and Haskel 2003).

The OECD core model and some extensions to it

According to Criscuolo (2008), the CDM framework structurally models the innovation investment decision, the innovation process and the role of innovation in the production of output. It corrects for two main problems that affect this type of analysis: selectivity and endogeneity, due to the fact that some of the explanatory variables in the model are simultaneously determined as dependent variables. CDM model takes both these problems into account in three steps. In the first step firms decide whether and how much to invest in R&D. In the second step the model relates the given investment in R&D to innovation outputs, defined either as innovative sales or as number of patents using a knowledge production function. Finally in the third step CDM estimates an augmented Cobb-Douglas production function that describes the relationship between innovation output and productivity.

Like the CDM model, the OECD core model (Criscuolo 2008) has three stages and consists of four equations. The first stage explains firms' decision to engage or not in innovation activities and the decision on the amount of innovation expenditure. In the first equation the probability that a firm will innovate depends on the size of the firm, measured as log employment; whether the firm is part of a group (dummy); whether the firm serves a foreign market (dummy); whether it experienced obstacles to innovation and the industrial sector which it belongs to. The choice of these covariates is mainly dictated by the availability of information for non-innovative firms in innovation surveys across all countries.

For a given probability to innovate, the second equation of the first stage models an innovation expenditure intensity equation, where the dependent variable is log innovation expenditure per employee. In addition to the regressors in the first equation, the intensity to innovate is modelled also to depend on whether the firm has cooperation activities and whether the firm has received public financial support.

The second stage models the knowledge production function where the dependent variable, log of innovative sales per employee, depends on the intensity of investment in innovation; firm's size; the firm being part of a group; process innovation (dummy) and different types of co-operation the firm engages in and industry dummies. Since the model is estimated only on innovative firms, the estimation technique controls for selectivity. In addition, it controls for potential endogeneity, which might arise because of unobserved heterogeneity or omitted variables or because of reverse causality (e.g. innovation surveys ask for innovation inputs and output in the same year).

The third stage estimates the innovation output productivity link using an augmented Cobb–Douglas production function. The dependent variable is log sales per employee. The right-hand side variables included are size; a dummy for group; process innovation; and log innovative sales per employee. Again, selectivity and potential endogeneity are dealt with by appropriate econometric techniques.

The measure of productivity, log total sales (turnover) per employee, is a very simple one. For some countries, including Finland, it was possible to extend the analysis to control for other factors such as human capital and physical capital in the production function. Second, the model is estimated only on innovative firms, where a firm is defined as innovative if it has positive innovation expenditure and positive innovative sales.[2] Also a broader definition of innovative firms was used based on positive innovation expenditures only.

The innovation survey data could be further enhanced with panel data including firm-level information on sales, employment, profit, value added, physical capital and the level and field of education of employees (Lööf 2002). Model specifications could also be enhanced. For example, being a performer of continuous R&D can be expected to relate closely to innovation. A factor affecting a firm's decision to engage in innovation activities is its past innovation activities. The use of patents and trade secrets which is associated with past innovation is a strong predictor of being an innovator. Determinants of innovation (R&D) intensity may consist not only of the latest innovation expenditures, export orientation, innovation cooperation, R&D subsidies, product and process orientation, firm size, but also of R&D stock.

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[2] Both of these conditions are not necessary for a firm to be innovative in the approach used in this study and based on the information whether a firm had abandoned or ongoing innovation projects or introduced an innovation during the reference period (t1–t3). A firm can be innovative without any innovation expenditures and more so, without any innovative sales in year t3 during the reference period.

Table 7. Innovation and productivity – a more systemic approach, empirical findings and expectations.

Joint determination of innovativeness and firm performance, joint determination of innovation input and the organisation of innovation process (collaboration, extramural R&D, other sources). First results: R&D capital induce innovation (patents) which contributes to productivity growth, innovations depends on the level of current and past R&D investments. Past performance has usually a significant positive effect on the growth rate of R&D inputs, on the realisation of innovation or on innovative sales. Innovation outputs were observed to contribute to a firm's total sales growth. R&D co-operation, extramural R&D and other information sources may affect innovation expenditures and also directly the level of innovation output In the CDM model firms' size, industry, diversification, market share, demand pull, technology push affect R&D activities. These adds to knowledge capital which generates innovation which in its turn affects productivity. In a revised CDM model, knowledge is measured by innovation output. Also revised models based on the selection of the appropriation strategy have been proposed. It is likely that IPRs and innovativeness are endogenous. The importance of appropriability conditions on innovation are incorrectly represented if this endogeneity is not taken into account. Also selectivity, if only innovative firms are considered, has to be taken into account. In a variant of the CDM model, used by the OECD Innovation Micro-data Project, the size, industry, enterprise group, exporting activities and obstacles to innovation explain the probability that a firm innovates. With a given probability to innovate, innovation expenditures per employee are explained e.g. with the co-operation activities and public R&D funding. Innovative sales per employee are explained with innovation expenditures per employee, the realisation of process innovation and different types of co-operation. Firm performance is measured with total sales per employee, and it depends on innovative sales per employee and process innovation, inter alia. The model controls except for selectivity also for endogeneity because of unobserved heterogeneity or omitted variables. The main finding of these studies is that innovation output affects positively firm performance. The results on the relationship between innovation and productivity growth are, however, mixed. Also the longitudinal relationship between firm level differences in R&D and productivity growth is typically statistically insignificant. Results are sensitive to the lag with which innovation strategies are allowed to impact productivity growth.

Critique

According to Malerba (2006) these models are increasingly successful in providing consistent answers and in improving the understanding of the link between innovation and firm performance. Great progress has been obtained in identifying, measuring and understanding stylized facts and statistical regularities, and the factors explaining them. This has begun to shed light also on the statistical properties of change in terms of industrial demography, entry and innovation, firm growth, stability of firm size distributions, and persistence in asymmetric firm performance. However, as shown e.g. by Hall and Mairesse (2006), there are still some serious econometric problems, and results are sensitive to model specifications. Unfortunately the cross-sectional nature of the CIS observations does not really allow a recursive equation system. Identification problem appears because innovation inputs and outputs occur simultaneously. There are problems in modelling innovation process from innovation input to innovation output. The analysis explains very little of the observed variance. According to Folkeringa et al. (2004), the inability to incorporate sufficiently detailed measures of innovation as a process is a problem in these studies.

Most studies examine innovation and growth during the same period and their results may be subject to simultaneity bias. These studies also focus too much on the latest innovation (or R&D) expenditures. In addition, according to Baldwin et al. (2004) high innovation (or R&D) intensity does not necessarily produce high innovative sales (weak relationship). Instead of the latest R&D expenditures, knowledge stock should be measured more broadly (extramural R&D, R&D cooperation, other knowledge sources); all these affect innovation output. Open innovation model associated with the work of Chesbrough (2003) emphasises the importance of organisational structures and skills to enable the take on and application of external sources of knowledge.

These studies typically define "innovative firms" as firms with innovation expenditure and/or innovation sales and represent the information on process innovation with a dummy variable.

A panel of innovative activities or at least a better survey design is needed

It would be better to have time series of innovative activity to create a true panel of firms. On the other hand, the internal timing problem between inputs and outputs in the existing innovation surveys could be overcome by changing the survey design. At present, including supplementary time series information on performance is the only solution. As regards to timing of inputs, we quite often have to assume that the level of R&D investments in year t3 can be used as an acceptable proxy for permanent R&D, i.e. referring also to some earlier years, implying that firms do not have large discrete increases or decreases in their R&D investments. In fact, studies of input measures by Peters (2005) and of output measures by Duguet and Monjon (2002) found the persistence in innovation activities to be high between R&D and innovation survey data, whereas they tend to be lower with patent and major innovations (Raymond et al. 2006). Raymond et al. tested the persistence of innovation using Dutch firm data from three waves of he innovation surveys, covering the periods 1994 to 1996, 1996 to 1998, and 1998 to 2000.

Innovation does not mean that only new, improved or recombined knowledge is relevant

The main objective of the knowledge production framework is to investigate the role of innovation in explaining the heterogeneity of firm performance. However, innovation does not mean that only new, improved or recombined knowledge is relevant. According to Knell and Nås (2006), equally important is the utilization of the whole range of capabilities that the firms possess, embedded in the routines of the organization, the competencies of the employees and the built in capabilities of machinery and equipment. In most studies, only the flow of new knowledge is usually taken into account, putting the knowledge stock aside. Knell and Nås argue that in order to understand differences in economic performance better an assessment of differences in knowledge management between firms should be integrated in the analysis.

Firms operate in constant interactions with their surroundings, such as their customers and other firms in the value chain. Firms belong to groups, nationally or internationally, or with other kinds of relationships. In addition, firms may exchange knowledge and information free of charge. Consequently, large parts of relevant knowledge are not recorded, at least not in quantitative terms. As pointed out by Griffith et al. (2006), only a part of firms engage in formal R&D, and not all firms undertake investment in innovation. Also Lööf (2002) points out that there are many different factors contributing to the innovation process such as the levels of human and knowledge capital, production organizations, labour relations, external network, work effort, managerial ability and firm strategy. The improved models should at least take into account the complexity of the innovation process and the heterogeneity of firm behaviour.

There are many information sources in addition to R&D

Innovation surveys allow us to examine the determinants of the output of the innovative process. In that respect, they differ from studies that focused previously on the input of the process, such as R&D. According to Baldwin and Gu (2004), the weakness of the earliest studies on the link between R&D activity and productivity growth relates to the inadequacy of using R&D or patents to measure the incident of innovation. R&D is only one input into innovation. In particular R&D is focused more on producing product than process innovations. Firms obtain ideas on innovation from a number of sources in addition to R&D, such as customers, suppliers, marketing or sales departments, and production departments. Patents are a complementary product of the innovation process, but not all innovations are patented.

Different measures of knowledge stocks: competencies and past innovation

In the knowledge or innovation production function models where innovation in a period is a function of R&D inputs and existing knowledge stock within the firm, we have at least two measures of knowledge stock: set of competencies (highly educated persons) and past innovation of the firm approximated by the use of patents or trade secrets in the past. Since a considerable lag exists between the date when a patent application is filed and the date it is granted, the fact that a firm is using patents indicates that the firm was innovation active in the past and thus has developed innovation competencies. The competencies in areas of technology, production, human resources management and marketing have been shown to be essential for innovation (Baldwin and Hanel 2003; Leiponen 2000b). According to Baldwin et al. innovators require technical competencies related to production processes. They also need skilled workers what requires the development of human resource management strategies for training and the retention of knowledge workers. Innovating firms have to penetrate new markets, and this requires special marketing capabilities. Innovating firms require also a special type of capital that supports soft assets related to knowledge development and this in turn requires a special type of financing skills. The skills and competencies that a firm builds up over time are important foundations for the conducting of innovative activity. It has been found out, that successful innovations are more closely related to firms' existing ranges of technological and marketing skills than unsuccessful ones (Baldwin and Hanel 2003).

Past performance and innovation

As Baldwin and Gu (2004) finds, strong growth in the past may contribute to high innovation. Baldwin et al. constructed two measures of past growth: labour productivity growth and market-share changes over a period before the introduction of an innovation. The set of control variables includes firm size and age, ownership (foreign- vs. domestic-controlled plants) and an indicator for export intensity. Each of these is a proxy to firm specific knowledge assets that are not captured by the measures of competencies and innovation activities of a firm. They also included a set of industry fixed effects that control for industry specific demand-pull and technology-push factors that are common to all firms within the industry. The measures of innovations refer to the period 1989−1991. The past growth variables are calculated over the period 1985−1989. Baldwin et al. used a probit regression for the incidence of innovation, because the dependent variable is a binary variable, which takes a value of one for innovating firms and zero for non-innovating firms. For the number of innovations and the share of sales from product innovation they used ordered probit regression because the dependent variable is constructed as intervals.

Innovation may affect market share through productivity or through introduction of new products

The study of Baldwin and Gu (2004) poses two questions that are at the heart of these studies. First, what are the characteristics of producers who introduce innovations? Second, is innovation linked to performance – i.e. to productivity growth, market-share changes and survival of individual firms? The framework for their analysis is straightforward and has been adopted in previous work by Baldwin and Sabourin (2001) and Baldwin et al. (2004). Firms are seen to make a choice as to whether they will try to be innovative. Some firms that do so will succeed in introducing an innovation. Past performance may condition the likelihood of success in doing so. In turn, the introduction of an innovation may affect labour productivity in the future, particularly if the innovation involves the use of new processes. Productivity gains will then impact on market share through its effect either on relative prices or on the quality of product. Innovation may affect market share indirectly through its impact on productivity but also directly through its effect on the introduction of new products.

The partial panel data allow the examination of the dynamic interaction between innovation and performance

Baldwin and Gu (2004) extend their earlier findings by focusing not just on small firms but on both large and small firms. They use partial panel data which allow the examination of new aspects of the dynamic interaction between innovation and performance. They develop a detailed profile of firms both before and after the 1993 Innovation Survey. Like we do in this study, they consider three periods: three-year period over which innovation is measured, the time period prior to innovation, and a time period after innovation. The question posed by Baldwin et al. (ibid.) is whether past growth is related to the successful innovation during a subsequent period. Strong growth can have positive feedback effects and strong growth in past may contribute to high innovation rates. They constructed two measures of past growth: labour productivity growth and market-share changes over a period before the introduction of an innovation. Growth facilitates learning and leads to the accumulation of the type of internal competencies that are essential for innovation. The data set also allows them to ask whether innovation affects future growth. Most studies in other countries examine innovation and growth during the same period (van Leeuwen 2002; Lööf and Heshmati 2001; and Criscuolo and Haskel 2003) and their results may be subject to simultaneity bias.

Not all innovations have the same impact on firm performance

While the focus of the study of Baldwin and Gu (2004) is on innovation, they note that not all innovation might be expected to have the same impact on firm performance. Innovations differ depending on whether they involve new products, new processes or some combination of the two. Innovations differ in terms of novelty. Baldwin and Gu use different measures of the degree to which a firm is innovative, i.e. measures of both incidence and intensity of innovation. In addition, there is information in the Canadian innovation survey whether a major innovation was introduced, the percentage of product sales that come from a major innovation, and the number of major innovations that were introduced. The latter two give measures of intensity how much innovation occurred.

There is significant heterogeneity between firms; innovativeness is of crucial importance for the high-growth firms

Another criticism is that previous studies have lumped together firms from all manufacturing sectors – even though innovation regimes vary dramatically across industries. In a study made by Coad and Rao (2006), the focus was on specific 2-digit and 3-digit sectors that were hand-picked according to their intensive patenting and R&D activity. Coad and Rao report that even within these sectors, there is a significant heterogeneity between firms, and using standard regression techniques to make inferences about the average firm may mask important phenomena. They used quantile regression techniques to investigate the relationship between innovativeness and growth at a range of points of the conditional growth rate distribution, and observed that, whilst for the "average firm" innovativeness may not be so important for sales growth, innovativeness is of crucial importance for the "superstar" high-growth firms.

The longitudinal relationship between firm-level differences in R&D and productivity growth is typically insignificant.

According to Coad and Rao (2006), mainstream economists typically view heterogeneity as related to conduct and performance as a temporary phenomenon. This proposition of non-persistent heterogeneity has been challenged from a theoretical as well as an empirical point of view. For example, when controlling for differences in innovation investments and human capital, knowledge-intensive manufacturing firms are not more innovative than labour- or capital-intensive manufacturing firms (Lööf 2002). Much of the heterogeneity is quite persistent over time. Bartelsman and Doms (2000) find that the amount of productivity dispersion is considerable and persistent in nature, implying that highly productive firms today are likely to be highly productive firms tomorrow as well. The literature also shows that R&D expenditures are highly correlated from year to year. However, the longitudinal relationship between firm level differences in R&D and productivity growth is typically statistically insignificant. R&D effects are intrinsically uncertain. They often occur with a long lag and may vary significantly from one firm or sector to another and change over time (Mairesse and Sasseneou 1991). They may also be hidden by the effects of other factors of production and the productivity which occur simultaneously and may largely dominate them. However, the impacts of learning curve effects and learning by doing and learning by co-operating on labour productivity should not be neglected.

Innovation studies based on CIS are usually biased towards internally generated knowledge

Innovation Surveys allow researchers to study the determinants of investments in innovation, the knowledge production function controlling for non-R&D inputs, cooperation activities between firms and with universities, the role of trade (exports) and foreign ownership on innovation outcomes, the role of innovation activity for firm performance and employment, the role of innovation policies and strategies to protect innovations. Other data with which Innovation Surveys can be matched include production data, financial data, patent data, and data containing detailed information on foreign ownership and multi-nationality. From production data information on past/subsequent performance of firms can be drawn. From balance sheet data we can get information on financial conditions of firms and on their profitability measures. Skills data can be taken from employee surveys or census. Studies based on CIS can broadly be categorised into three groups: studies of the innovation process (innovation expenditure and knowledge production function), studies of the role of innovation on firms' performance, studies that look at both determinants of innovation and its role for firms' performance (the CDM model). In the CIS there is, however, a bias towards internally generated knowledge. In real life external knowledge is also important to innovation.

The economic effects of innovation are highly differentiated

The economic effects of innovation are highly differentiated depending on the innovation strategies of firms, e.g. on strategies of technological competitiveness and cost competitiveness. Technological competitiveness emerges through knowledge generation, R&D, product innovation and new markets, cost competitiveness through process innovation, greater capital intensity, job reductions, labour saving investment, flexibility and restructuring (Pianta 2005). There is a difference between product and process innovations and their effects, between types of innovation inputs/activities, objectives pursued, the sector/markets where firms operate in, types and levels of knowledge opportunities and demand conditions. The research questions often posed are as follows: Are economic performances affected by innovation? Are innovation activities in turn stimulated by past economic performances? Is there a cumulative self-reinforcing relationship? What kind of strategies and innovation inputs do affect the performances of certain industries and firms? (Cainelli et al. 2005).

Also the economy wide effects of innovation are different

Pianta (2005) argues that the productivity puzzle disappears when the economy is split according to the two alternative models of technological competitiveness or cost competitiveness. Productivity growth should be explained by splitting the economy to sectors dominated by product/service innovation, where research activities and market strategies are the key sources of technological competitiveness, and to sectors dominated by process innovation, where innovation embedded in capital equipment and strategies oriented to cost competitiveness are dominant. Countries should be characterised by different structures (sectoral compositions) and relevance of such strategies. Demand pull and technology push as well as sustain productivity growth can be observed in both models, but with a different content of innovative efforts. For example, wages increase faster in sectors and countries where innovation expenditures are higher and product-based innovation expands turnover.

Table 8. Innovation and productivity – a more systemic approach, critics against these studies.

These studies typically define “innovative firms” as firms with innovation expenditures and/or innovative sales and represent the information on process innovation with a dummy variable. Reverse causality problems appear because innovation inputs and outputs occur simultaneously in the CIS data. In addition, results are often sensitive to model specifications.

A focal problem in these studies is their inability to incorporate sufficiently detailed measures of innovation as a process. Innovation regimes may vary dramatically across industries and across firms. Innovativeness may not be so important for sales growth for the “average firm”, but it may be of crucial importance for the “superstar” high-growth firms.

These studies focus too much on the latest innovation expenditures. Instead of the latest innovation expenditures, knowledge stock should be measured more broadly (extramural R&D, innovation collaboration, other knowledge sources), because all these affect innovation output. Open innovation model emphasises the importance of organisational structures and skills to enable the take on and apply the external sources of knowledge. Differences in knowledge management between firms should be integrated in the analysis. The impacts of learning by doing and learning by co-operating on innovation and on labour productivity should not be neglected.

3.8 R&D cooperation

Determinants of R&D cooperation

A number of empirical studies have explored the determinants of R&D cooperation (e.g. Kleinknecht and Reijnen 1992; Fritsch and Lukas 2001; Tether 2002b; Belderbos et al. 2004). A major finding of recent contributions is that the goals and, hence, the determinants of R&D partnerships differ depending on the type of R&D and cooperation partner. Fritsch and Lukas (2001) find for German manufacturing firms that innovative effort directed at process improvement is more likely to involve cooperation with suppliers, whereas product innovations are associated with customer cooperation. Tether (2002b), using UK data on innovating firms, finds that R&D cooperation is mostly the domain of firms pursuing radical innovations rather than incremental Innovations. Belderbos et al. (2004) find substantial heterogeneity in the determinants to engage in R&D collaboration with different partners. Cooperation with a type of partner generally is more likely to be chosen if that type of partner is considered an important source of knowledge for the innovation process, while knowledge sourced from universities and research institutes positively impacts all types of cooperation. R&D cooperation with universities is more likely to be chosen by R&D intensive firms in sectors that exhibit fast technological and product development.

Different types of collaboration may serve different purposes

Explanations for collaborative R&D that have been extensively discussed revolve around factors such as sharing risks and costs in the face of uncertain technological developments (Das and Teng 2000; Tyler and Steensma 1995), shortening innovation cycles (Pisano 1990), the pursuit of efficiency gains such as economies of scope and scale or synergistic effects through efficient pooling of the firms' resources (Kogut 1988; Das and Teng 2000), learning through monitoring technology and market developments (Roberts and Berry 1985), dealing with regulations and industry standards, and responding to government subsidy policies (Benfratello and Sembonelli 2002; Nakamura 2003). R&D alliances may be a source of competitive advantage and they have lasting effects on firm performance. It has also been suggested that different types of collaboration may serve different purposes, where the two main goals of innovative effort are cost reduction and market expansion.

Inter-firm knowledge flows, knowledge spillovers

Also in the management domain a large body of literature has been produced that discusses various motives that incite firms to collaborate on R&D (Contractor and Lorange 2002; Nooteboom 1999). In parallel, a stream of literature in industrial organization theory has taken a game theoretical perspective to focus on the relationships between R&D cooperation, R&D investment, and inter-firm knowledge flows. The latter literature has been most concerned with the potential impact of R&D cooperation and knowledge spillovers on R&D investment levels, and has largely been restricted to the analysis of cooperation with competitors. By and large, the findings suggest that the presence of effective knowledge spillovers between firms provides incentives for R&D cooperation, which in turn leads to higher R&D investment levels.

Differences in firms' innovation output

The key question whether cooperative R&D has an impact on firms' (innovation) performance has remained largely unexplored in both the industrial organization as well as in the management literature (e.g. Tether 2002b; Das and Teng 2000). A number of papers have included a cooperation variable in empirical models explaining differences in firms' innovation output (Janz et al. 2004; van Leeuwen and Klomp 2001; Klomp and van Leeuwen 2001; Lööf and Heshmati 2002; Monjon and Waelbroeck 2003; Criscuolo and Haskel 2003), but most of these studies have been primarily concerned with the impact of R&D investments on performance and did not examine systematically differences in impacts across cooperation types. Management studies have restricted analysis to particular performance indicators in specific industries, e.g. the effect of finances on high-tech start-up firm performance in the biotechnology industry (Baum et al. 2000), or the effect of learning in alliances on market share performance of the automotive industry (Dussauge et al. 2002).

Connection between R&D cooperation and innovation performance

A number of empirical studies have found positive impact of engaging in R&D cooperation on innovation performance, i.e. sales of innovative products (Klomp and van Leeuwen 2001; Janz et al. 2003; Janz et al. 2004; van Leeuwen 2002; Lööf and Heshmati 2002; Criscuolo and Haskel 2003), patenting (Vanhaverbeke et al. 2002), and sales growth (Cincera et al. 2004). Some of these papers have also examined the effect of different cooperation types, but have produced ambiguous results. Cincera et al. (2004) distinguished between overseas and domestic R&D collaboration by Belgian firms and found a positive impact on productivity of the latter but a counter-intuitive negative impact of the former. Lööf and Heshmati (2002) included a selected group of cooperation types in an innovation output equation for Swedish firms and found that cooperation with competitors and universities impacted innovation output levels positively, but cooperation with customers negatively. As the above studies use cross-sectional data drawn from a single CIS survey, the ambiguous results may be partly attributed to the difficulties in allowing for an appropriate lag with which cooperative R&D impacts innovative output and performance. Furthermore, if there are unobserved firm characteristics that at the same time impact firms' incentives to cooperate and their innovative output, a positive correlation between cooperation and innovation output may be spurious rather than causal (Klomp and van Leeuwen 2001).

The role of inter-firm knowledge spillovers in productivity growth

There is a large body of empirical literature examining the sources of productivity growth and in particular, the role of inter-firm knowledge spillovers. These studies have generally confirmed that knowledge spillovers that may arise from interaction with other firms through international trade, foreign direct investments, and input-output linkages, have a positive impact on productivity growth. Similarly, empirical studies have documented the positive impact of own R&D on productivity at the firm level. A related literature has been concerned with the role of foreign multinational enterprises (MNEs) in productivity performance (Griffith 1999; Harris and Robinson 2003). The literature suggests that an analysis of different types of cooperation strategies should take into account the different possible aims of (collaborative) innovation efforts. Labour productivity increases may reflect incremental innovations and may be affected by collaborative R&D aimed at cost reductions, while sales expansion through innovative products is more likely to be related to basic R&D effort and client collaboration.

A major heterogeneity in the rationales and goals of R&D cooperation

Belderbos et al. (2004) analyse the impact of R&D cooperation on firm performance differentiating between four types of partners (competitors, suppliers, customers, and universities and research institutes) and considering two performance measures: labour productivity and productivity in innovative (new to the market) sales. They examine the impact of R&D cooperation in 1996 on subsequent productivity growth in 1996−1998. The results confirm a major heterogeneity in the rationales and goals of R&D cooperation. Competitor and supplier cooperation focus on incremental innovations, improving the productivity performance. University cooperation and main competitor cooperation are instrumental in creating innovations generating sales of products that are novel to the market, improving the growth performance of firms. Customers and universities are important sources of knowledge for firms pursuing radical innovations, which facilitate growth in innovative sales in the absence of formal R&D cooperation.

Competitor collaboration has multiple purposes

The results of Belderbos et al. (2004) show that R&D cooperation affects innovation expenditure intensity and incoming spillovers have independent impacts on productivity growth (with the exception of innovation intensity in the innovative sales equations). The results diverge once spillovers and cooperation are differentiated by source and partner. Competitor collaboration is the only type of collaboration that has multiple purposes and impacts, and is effective in generating both labour productivity increases (e.g. through cost sharing in R&D) and increases in innovative sales per employee enabling the start of innovation projects through risk sharing and improving sales through the establishment of technological standards. Belderbos et al. find that supplier and competitor cooperation have a significant impact on labour productivity growth, while cooperation with universities and research institutes, and competitor cooperation positively affects growth in sales per employee of products and services new to the market.

Effects on labour productivity growth and innovative sales productivity growth

The goal of the empirical analysis of Belderbos et al. (2004) was to determine whether different types of R&D collaboration affect a firm's growth in labour productivity and innovative sales productivity. Labour productivity growth will be affected most by cost reducing innovation, while innovative sales productivity growth is more affected by demand expansion oriented product innovation. Belderbos et al. follow the suggestion in the literature that analysis of the performance effects of R&D cooperation should control for the positive impact of incoming knowledge spillovers, as well as R&D expenditures, while the existence of multinational group linkages should also be taken into account. The potential bias of unobserved firm characteristics can be reduced by including lagged productivity levels as an explanatory variable.

Full impact of formal cooperation

The analysis of Belderbos et al. controls for the potential impact of incoming knowledge flows that are not due to R&D partnerships, as well as for the effect of the firms' own R&D expenditures. Since Belderbos et al. are interested in estimating the full impact of formal cooperation, they separate spillovers due to purposeful informational exchanges that arise in formal cooperative arrangements from spillovers that are not due to such cooperation (e.g. arising from market contacts with suppliers and customers). Whereas the four knowledge spillover variables included in the model identify the source of the spillover, there are a number of other types of incoming spillovers in the CIS that identify the channel of the spillover (databases, trade fairs, patents).

The source specific spillovers are apparently able to capture the impact of incoming knowledge on productivity growth. Hence Belderbos et al. (2004) posit that cooperative R&D projects in 1994−1996 have their main impact on productivity growth in the 2-year period 1996−1998. R&D efforts require some time to translate into innovative output and productivity advances. Hence, effective spillovers in 1994−1996 (the 1996 CIS) are likely to have their main impact on the 1996 productivity level rather than on subsequent productivity growth in 1996−1998. The R&D measure used here is total innovation expenditures as percentage of sales. The variable also controls for the impact of external technology acquisitions. Group firms may show higher growth rates if they can draw on technology and organizational expertise from headquarter and other groups firms.

Belderbos et al. include demand-pull and cost-push variables in the model as controls. The demand-pull variable is a sum of scores on the importance of objectives of innovation relating to demand factors. Cost-push is the sum of scores on importance of objectives relating to cost reduction. As stated by Belderbos et al., these simple mean comparisons cannot be taken as evidence of the impact of cooperation strategies on productivity, as this requires controlling for initial productivity levels, industry differences, and the joint impact of the other variables in a multivariate analysis. Results from the aggregated specification for labour productivity growth strongly confirm the contribution of R&D cooperation to productivity growth. Productivity growth is also higher for affiliates of foreign multinational firms and higher for domestic group firms, while firm size and the direction of innovative efforts (demand enhancing or cost saving) have no appreciable impact.

Competitor collaboration has an impact on labour productivity growth

In the study by Belderbos et al. (2004), only competitor collaboration is found to have an independent positive impact on labour productivity growth, when spillovers and collaboration are differentiated by type of partner and source. Competitor collaboration gets a marginally significant impact for persistent collaborators. A demand orientation is more likely to translate into growth in new product sales, but a cost orientation has a negative impact. Firms that devote more R&D efforts to cost reduction are not able to devote a much attention to market expansion and perform less in this type of productivity growth. A past leading performance in innovative sales productivity is more difficult to sustain than a lead in labour productivity.

The results are sensitive to the lag with which innovation strategies are allowed to impact productivity growth. The results confirm a major heterogeneity in the rationales and goals of innovation collaboration, with competitor and supplier collaboration focused on incremental innovations improving the productivity performance of firms, while university collaboration and again competitor collaboration are instrumental in creating and bringing to market radical innovations, generating sales of products that are novel to the market, and hence improving the growth performance of firms (Klomp and van Leeuwen 2001). The findings provide qualified support for the notion that cooperating firms are generally engaged in higher level innovative activities (Tether 2002b). This holds for firms collaborating with universities (e.g. to get access to basic research) and competitors (to allow R&D for risky projects), but not for firms engaged in vertical cooperation with suppliers and customers.

Table 9. Collaboration in innovation and sales expansion, empirical findings and expectations.

Collaboration with competitors and universities impact innovation output levels like the innovative sales per employee. Also knowledge spillovers from international trade, foreign direct investment and input-output linkages may have a positive impact on innovation output or on productivity growth. Sales expansion through innovative products is likely to be related to R&D efforts and client collaboration. Results also suggest that collaboration in innovation (e.g. in marketing) contributes directly to sales growth. Competitor collaboration may have multiple targets. The targets can include incremental innovations improving the productivity of the firm or/and creating radical innovations (e.g. by risk sharing) and improving the sales growth of the firm.

4. Hypothesis on innovation and firm growth

In this study we are mainly interested in the longer term post-innovation growth performance of innovative firms differentiated by type and novelty of innovation and by the origin and size classes of firms, and compared with that of non-innovative firms. The approach used in this study is somewhat similar to the one used by Baldwin et al. (2004) when examining whether innovation is linked to firm performance, i.e. to productivity growth or changes in market-share. Like Baldwin et al. we focus on both large and small firms and develop a time profile for these firms both before and after the innovation period. Then past growth is related to the successful innovation during a subsequent period and successful innovation is related to the post-innovation growth performance. The panel data on firm performance allows us to examine the dynamic interaction between innovation and firm performance.

Also Klomp and van Leeuwen (2001) used similar performance measures what we are using in this study: the average growth rates for total sales, productivity and employment for respectively innovating firms, non-innovating firms and the full sample, but they compiled the average growth rates for the innovation period only. Most innovation studies based on the Community Innovation Surveys (CIS) relate innovation in a period to growth in the same period. However, during the period when the innovation is introduced, there is probably a smaller difference in the growth in sales, productivity and employment between innovating and non-innovating firms or between product innovators and process innovators than after innovation. The effect of innovation shows up mainly in the post-innovation period rather than in the innovation period.

Here, innovative (innovation active) firms have been defined as firms that have introduced an innovation or have ongoing or abandoned innovation projects during a three years reference period given in the CIS. This definition corresponds to the filter question used in the questionnaire. We do not use innovation expenditures or innovative sales as criteria for innovativeness for many reasons. First of all, innovation expenditures of firms are often quite unreliable, especially for firms that do not report any innovative sales during the reference period, and are sometimes not even checked in the Finnish CIS. The main effort in these surveys has been put on the dichotomous variables of being innovative or not.

If there is no product or process innovation or innovation project in the reference period a firm is judged to be non-innovative. This approach for estimating the effects of innovativeness is reasoned especially for small firms or entrants in their early phases. It has sometimes been argued that not innovations, but innovativeness, i.e. knowledge sourcing and innovation activities in general matter when innovative firms are compared with the non-innovative ones (Piekkola 2006).

Revealing the determinants of the post-innovation growth bursts is, of course, difficult. They may be hidden by the effects of other factors of production and productivity which occur simultaneously and may largely dominate them. The samples of firms used in the inference may have serious selectivity biases and the observed firm characteristics may encompass simultaneity problems, and real panel data for innovative firms do not normally exist. A partial panel data we, however, are able to construct by matching cross-sectional CIS data with panel data drawn from other official sources. The panel data for firm performance and characteristics except for the size of their R&D activities can be taken from these sources. They can be divided into pre-innovation, innovation and post-innovation periods.

4.1 Hypothesis on the determinants of growth performance

We examine here the role of innovation in the growth performance of firms in the manufacturing sector as well as in the knowledge intensive business services. We make a distinction between product innovations and process innovations. Furthermore we distinguish radical, new to market innovations from incremental innovations. Improvements of internal processes (process innovations) are associated with a more efficient innovation process, i.e. the transition from innovation input into innovation output. This improved efficiency is expected to have a significant positive effect on turnover (sales) growth (Hypothesis 1). Turnover growth can be taken as a crude approximation of productivity growth, particularly in services (see Lööf 2002). On the other hand, as pointed out by Baldwin et al. (2004), in the early stages of firms, innovation is not expected to be closely related to productivity gain. However, a priori we expect a positive relationship between innovation and productivity growth. We assume that in a shorter time period for small firms, product innovation affects their sales growth and number of employees, but not necessary growth in labour productivity. We, therefore, write our second hypothesis in a form: product innovation affects the growth in sales (Hypothesis 2).

We can also set up a hypothesis that the growth in sales of product innovators is higher than the growth in sales of non-innovative firms (Hypothesis 3). Past economic performance, e.g. sales growth, may in turn affect firms' innovativeness and especially the introduction of innovations. At the same time it may affect firms' collaboration behaviour and innovation expenditures. Furthermore, collaboration in innovation may contribute directly to the total sales growth. We can therefore, also pose a hypothesis that collaboration in innovation (e.g. in marketing) affects the growth performance of firms directly (Hypothesis 4). Furthermore, we can postulate that spin-off entrants have a higher growth performance than other firms because of the recruitment of skilled employees from parent firms to spin-offs (Hypothesis 5). For this study, spin-off firms have been matched from an outside source based on a questionnaire conducted for large manufacturing firms in certain technology based sectors (see Lehtoranta 2010). A tentative identification of these spin-off firms was carried out by using the Business Register and the longitudinal panel data of the Employee-Employer Data. The origin and parent for these firms was then confirmed by an enquiry.

Table 10. The hypotheses posted in this study.

Hypothesis 1: Process innovation is expected to have a significant positive effect on the growth in sales.
Hypothesis 2: Product innovation is expected to have a significant positive effect on the growth in sales.
Hypothesis 3: The growth in sales of product innovators is higher than the growth in sales of non-innovative firms.
Hypothesis 4: Collaboration in innovation affects the growth performance of firms directly.
Hypothesis 5: The spin-offs of large firms have a higher growth performance than other firms.

4.2 Propensity to innovate; innovative firms and product innovators

We first study the characteristics of innovative firms, i.e. firms having reported in an innovation survey that they have conducted innovative activities within the reference period. As mentioned earlier past growth performance may affect firms' innovativeness and especially the introduction of innovations. Except for past performance, the innovativeness of a firm in a reference period may be related to its size, export share, the level of productivity, past patenting activities, the share of highly educated employees and sector. All these company characteristics are drawn from other sources than CIS. Here we use the full sample of CIS firms matched with a panel of production and education data in order to get information on the characteristics of innovative companies compared to non-innovative companies also included in the CIS samples.

We proceed from this to investigate what factors lead some firms to succeed in introducing a product innovation and others to fail. We use both the full sample and the sample of innovative firms, and we only use information that exists for all the firms in the full sample. This approach does not, however, totally avoid the possible sample selection biases in the CIS samples. There may be, for example, a bias towards small technology based firms if not corrected for with weighting factors. In a later stage, we use the characteristics of innovative firms and especially product innovators together with a Heckman selection model, when the determinants of the post-innovation growth performance are examined.

In our study the binary variables on innovation efforts like innovation projects and occurrence of innovation differentiated by types of innovation, and in some models innovative sales in total sales are the only innovativeness measures to be considered. The reason for this is simple: we believe that in the CIS samples the quality of innovation expenditures and innovative sales is not as good as is the binary information on innovativeness.[3] The other reason for using the wide definition of innovation active firms is the fact that we hereby avoid problems related to intramural and extramural R&D expenditures.[4] In our approach, R&D expenditures (innovation expenditures) are not used to make a distinction between innovative and non-innovative companies. Firms may well introduce innovations without in-house R&D. In addition, the data on extramural R&D expenditures may not be reliable. We, however, relax this statement a bit later and also investigate the results based on the quantitative connection between total innovation expenditures, innovative sales and productivity by using a variant of the CDM model. This is done mainly for comparison purposes.

In the Heckman selection model, the continuous variables like in-house R&D investment, and binary variables capturing the impact of continuous R&D and collaboration in innovation cannot be used as explanatory factors for innovation incidences (innovation dummies), because by definition they exist only for innovative firms, and are asked innovative firms only. Instead, the obstacles to innovation and IPR issues can be used in CDM based models, because all firms have been asked about obstacles to innovation and about their patenting behaviour.

Baldwin et al. (2004) found that R&D investment, competencies and past innovation activities are the three main factors affecting innovation outcomes (innovation incidences or innovative sales) of Canadian manufacturing firms. We also can assume that the previous patenting behaviour and the human resources

[3] Since innovative sales growth may contribute to the total sales growth, it is enough to consider innovative sales. This assumption is, however, not used here because of data constraints. Also Baldwin et al. (2004) point to the difficulty to measure the amount of sales that come from a product innovation, especially if the innovation is incremental and is an add-on to an existing product.

[4] It is well known that the intramural R&D expenditures may not capture non-formal R&D made e.g. in small firms or in the services sector. In addition, in the CIS data R&D expenditures (innovation expenditures) only refer to the latest year of the reference period.

have a significant positive effect on the propensity of being innovative as well as on the propensity of being an innovator, and that R&D intensity affects the share of innovative sales. Here, a firm is defined to be an innovator if it has introduced an innovation in the reference period. If it only has innovative efforts but not innovations in the reference period, it is defined to be innovative but not an innovator. Continuous R&D can also be expected to closely relate to innovation of most types. If we only consider innovative firms, we can also explain the innovation propensity by the amount of innovation (R&D) investment.

Normally, innovation outputs and R&D intensity affect labour productivity, and it is assumed that this contributes to the expansion of firms. Here we assume that in a shorter time period for small firms, product innovation affects their sales growth and number of employees, but not necessary their labour productivity measured by sales per employee.

5. Empirical testing of the hypothesis

5.1 Data and the estimation method

We use two waves of the Community Innovation Survey, CIS2 and CIS3 and mach them separately with the turnover (sales) and employment data for the 1989–2004 period taken from the Business Register, with the patent data taken from the Patent Register and with the education data taken from the Employee-Employer Data. CIS2 refers to the period 1994–1996 and CIS3 to the period 1998–2000. Statistical units in the CIS samples are independent enterprises or members of enterprise groups. However, response at the group level is also allowed in the Finnish CIS. This may cause problems when linking CIS data with data taken from other sources, because these other data typically are based on enterprises, not on groups of enterprises.

The selection of the CIS samples is based on the stratified simple random sampling technique, with census for enterprises with 100 or more employees. Stratification variables in the CIS3 are: economic activities (NACE 2-digit level), enterprise size (10–19, 20–49, 50–99, 100 or more employees) and regions (NUTS2 level). The target population includes all enterprises being active in Finland with at least 10 employees in the following NACE activities: sectors C, D, E, 51, I, J, 72, 73, 74.2, 74.3. CIS2 also includes some innovative micro firms with less than 10 employees.

Innovation expenditures in CIS2 and CIS3 are largely based on replacement and imputations. The R&D expenditures of enterprises are compared with those of R&D Surveys and in the cases of remarkable differences the figures are replaced with those taken from R&D Surveys. Respectively, other expenditures like the acquisition of machinery and equipment for innovation activities are compared and possibly replaced with those taken from the Structural Business

Statistics (SBS). Also some basic information of enterprises is taken from the SBS. Imputation of missing items is based on the programmes given by Eurostat. Imputation is not used in questions on innovation activities (innovation incidences). Enterprises are asked to report whether they have introduced one or more product or process innovations, and whether they have abandoned or ongoing innovation projects during the reference period, usually over the last three years.

CIS2 and CIS3 also contain a panel of firms known to be innovative. Using a panel of innovative firms together with a random sample may induce a sample selection problem in both samples. Besides a sample selection problem there is another selection problem stemming from the fact that certain kind of firms conduct innovation activities and strive for innovations. On the other hand, in panels based on the Business Register, market exit may cause a selection bias. Selection effects can be accounted for by using e.g. Heckman two stage estimation model.

In the Heckman method, the sample of firms is cencored with an auxiliary variable (inverse Mills ratio) describing the selection of firms. The probability that a firm is selected into the sample or has responded, is expected to depend on its innovativeness. Innovation activities, on the other hand, are explained by the characteristics of firms: size of firms, export share in turnover, share of employees with tertiary education in technical, commercial and other fields, previous patenting activities and industries. Of these, at least the size of the firm, industry, the share of highly educated and the patenting activities of firms are assumed to correlate with the knowledge intensity of firms. Knowledge intensity of firms, on the other hand, is regarded as a selection criterium for the industries included. After estimating the selection equation (probit model) the predicted auxiliary variable will be placed into the OLS (and ML) regression model for the average growth rate in sales, labour productivity or in labour demand.

This is, however, a bit oversimplified view of how the effects of innovative output on the growth performance can be revealed. Omitted variables (e.g. market structure) may distort these effects, as may the non-linear relationships or unobserved heterogeneity of firms. In this study, we perceive that CIS3 gives quite a few significant estimates if the exceptionally weakly or strongly growing firms (outliers) are not excluded from the analysis. For this exclusion we use the STATA “hadimvo” procedure, as did Baldwin when analysing the Canadian panel of firms. This procedure, however, only circumvents the problem that we omit variables that could describe the reasons for these exceptions in the longer term growth rates (in sales or productivity). Because the exclusion of outliers does not have as remarkable effects on the estimates in the CIS2 sample than in the CIS3 sample, we conclude that the irregularities or unobserved heterogeneities in the longer term growth rates of firms have increased. The domestic market shares of firms were included in the regression both at the 2-digit and 3-digit level but were removed because they had no explanatory power. There is no information on the global market shares of firms in the statistical data sets.

We use innovation incidences (innovation dummies) and innovative sales as innovation output measures. In the study based on CIS2, sales growth is measured by the average annual growth rate in sales over the years 1989–1993 (pre-innovation period of 5 years), 1994–1998 (innovation period of 3 years plus a lag of two years), and 1999–2003 (post-innovation period of 5 years). In the study based on CIS3, sales growth is measured by the average annual growth rate in sales over the years 1991–1995 (pre-innovation period of 5 years), 1996–2000 (innovation period of 3 years plus a lag of two years), and 2001–2004 (post-innovation period of 4 years). The same has been done for the number of employees and sales per employee as a proxy for labour productivity. The average annual growth rates are given in log percentage changes (log percentage points) and are expressed in an index form (see Harabi 2003).

We relate a firm's innovation incidence during the innovation period (in CIS2: 1994–1996) to its average annual sales growth during a subsequent period (CIS2: 1999–2003) or alternatively over the years the firm was existing during this period. Allowing different ending years for some firms (for quite a few firms) benefits us in the number of observations. We do not have to omit firms having existed after the year 1998 or having some missing annual observations. This reduces the bias due to the market exit of firms. A small innovative firm has typically exited because some incumbent firm has acquired it. What we need here is at least one annual growth rate observation (needs data for two years) for each of the periods.

It follows from this approach that we cannot properly control for the business cycle effects. We do not use annual growth rates as such, because we think that they are strongly dominated by random walk. Instead we use period-specific data on firm's growth performance and characteristics. The dependent variable, e.g. the average annual sales growth is to be observed 5 to 7 years after the incidence of innovation. The general characteristics of the firms like their R&D intensity and the share of highly educated personnel are picked up from the last year of the innovation period. The R&D expenditures and the amount of export are available in the CIS for these years only.

As explanatory variables for the variation in the logarithm of the average annual growth rates over the post-innovation period we use the binary innovation occurrence variables categorised to product and process innovations, the binary variable describing the permanent R&D efforts and the binary variable describing the collaboration with partner firms categorised by different partner types over the innovation period, as well as binary variables describing sectors and the origin of the firm (spin-off or not). In addition we use some share variables, the share of R&D expenditures in turnover, the export share in turnover and the share of graduates in the personnel, categorised by types of education, in the last year of the innovation period. We also use lagged dependent variables, i.e. the logarithm of the average annual sales growth rates over the pre-innovation period to control for reversed causality, i.e. to control for the effects of firm growth actually inducing innovation, since strong firm performance creates resources to invest in innovation. The corresponding period-specific variables have also been compiled for the productivity growth rates and employment growth rates, when these are analysed. We therefore allow for a feedback effect from productivity to innovation output. Baldwin et al. (2004) used two measures of past growth as independent variables. They were productivity growth and market share changes during the pre-innovation period. We only use past growth performance (growth in sales, productivity or labour demand).

As the size variable of firms the logarithm of the number of employees is used. In some models also an index variable for firms diversifying their existing products or services are used. We also used variables that indicate a firm's market share decreasing, staying constant or increasing within each period as well as Herfindahl indexes on the sector concentration rates, but because they were statistically insignificant they were dropped from the models.

All models were estimated separately for the full sample, for the small and medium-sized firms, for innovative firms as well as for product innovators only. They were also estimated with and without Heckman selection model and with and without outliers in the growth rates. The Heckman two-step selection model was used to correct for a selection bias due to censored data. Also Lööf (2002) finds out that the impact of outliers is quite significant e.g. for the elasticity of sales growth for service firms.

Table 11. Determinants of innovativeness and the growth performance, expectations.

In this study, we explain the probability that a firm is innovative (i.e. has introduced an innovation or has ongoing or abandoned innovation projects during the reference period) with its size, sector, export share, the share of highly educated employees, the level of productivity, past patenting activities and past growth in sales (and in productivity). The shares of highly educated in different fields of education and past patenting activities by patent offices describe the competencies and technological knowledge of the firm. All these company characteristics are drawn from other sources than CIS. R&D investments cannot be used as factors affecting innovation incidences or innovation efforts because they are not known for the full sample of the CIS firms.

The post-innovation growth performance (average annual sales growth, employment growth, productivity growth) of an innovative firm is expected to depend on its size, sector, export share, past growth performance, product innovation, process innovation, collaboration in innovation by type and whether it was established as a spin-off firm of a large company. In the Heckman selection models, the full sample is used in the selection equation for innovativeness with the same explanatory variables as in the innovativeness regression except for the level of productivity. The sample of innovative firms is used for the determinants of growth performance. Also a variable describing R&D diversity is used as an explanatory variable.

In a variant of the CDM model used in this study, the size, sector, enterprise group, export share, past patenting activities by patent office and the share of highly educated employees in different fields of education explain the probability that a firm is innovative. With a given probability to be innovative, innovation expenditures per employee are explained with sector, enterprise group, export share, collaboration activities, continuous R&D and public R&D funding. Innovative sales per employee are explained with the size, sector, enterprise group, innovation expenditures per employee, the realisation of product and process innovation and different types of collaboration. Firm performance is measured with total sales per employee, and it depends on its size, sector, enterprise group, innovative sales per employee and product and process innovation, the share of highly educated employees in different fields of education and whether it was established as a spin-off firm. The model controls except for selectivity also for endogeneity.

5.2 Results

5.2.1 Innovativeness

The probability that a firm is innovative (i.e. has innovative efforts or has introduced a product or process innovation) within the reference period has been related to the following characteristics of firms:

I. large size of the firm
II. high export intensity
III. high level of productivity
IV. previous domestic patenting activity
V. high share of employees with tertiary education in technical fields
VI. high share of employees with tertiary education in fields other than technical and commercial
VII. high or medium high technology industry
VIII. low or medium low technology industry
IX. knowledge intensive services industry.

The relationship between these characteristics and the innovativeness of firms is a robust one and comes out both in the CIS2 and CIS3 samples. The results are quite similar for product innovators.

It is well known that good economic performance spurs innovation, and that high level of productivity and high rates of growth stimulate innovation activities. We find that previous sales growth affects the future innovation activities of the firms, and that large firms are more often engaged in innovation activities than small ones. In CIS2 active exporters are more often engaged in innovation activities than non-active exporters. In CIS3 the level of labour productivity is associated with the likelihood to conduct innovation activities.

Previous patenting activities, especially domestic patenting, affect the future innovation activities of the firms. The high share of employees with university level technical education has a significant and positive impact on the innovation activities of firms. The high share of employees with university level commercial or social education is not associated with the innovation activities of firms. Furthermore, the high technology and knowledge intensive services sectors have a positive and highly significant impact on the likelihood to conduct innovation activities. In CIS3 also low technology sectors affect positively the likelihood to conduct innovation activities.

Table 12. Determinants of the innovativeness.

Dependent variable	Innovation activities				Product innovation				Product innovation	
	All firms		SMEs		All firms		SMEs		All innovative firms	
	cis2	cis3	cis2	cis3	cis2	cis3	cis2	cis3	cis2	cis3
Previous average annual sales growth, log	++	+++	+	+++	+	+++	++	+++		
Number of employees, log	+++	+++	+++	+++	+++	+++	+++	+++	++	++
Export share in sales	+++		+++		+++		+		+++	
Productivity level										
Labour productivity, log		+++		+++		+++		+++		
Previous patenting activities										
Domestic applications, dummy	+++	+++	+++	+++	+++	+++	+++	+++		
EPO applications, dummy					++					
US granted patents, dummy				--				--		
Share of highly educated employees										
Technical education	+++	+++	+++	++	+++	++	+++	++		
Commercial or social education						+		++		
Other education	+++	+++	++	++	++	++	+	++		
Sector										
High technology	+++	+++	++	+++	++	+++		+++		++
High or medium high technology	++	+++	++	+++	++	+++		+++		+++
Low or medium low technology		+++		+++		+++		+++		+++
Low technology		++		++		+++	--	++		++
Knowledge intensive services	++		++	++	++	+++	++	+++	++	+++
Other services										+++

Note: +++(++, +) indicates significance for the positive relationship at the 1%,(5%, 10%) level
---(--, -) indicates significance for the negative relationship at the 1%,(5%, 10%) level

5.2.2 Post-innovation sales growth

We get strong evidence that the post-innovation average annual sales growth (over 5 years) is significantly and positively associated with the previous average sales growth (over 5 years) of firms, size of firms, product innovations, co-operation with foreign competitors, and with corporate spin-offs of large firms. In CIS3, the post-innovation sales growth is higher for the large firms than for the small ones. In CIS2, spin-offs of large firms grow faster than non-spin-offs. This concerns especially the innovative spin-offs. There are quite few known spin-offs that can be linked with the CIS3 data. This explains why CIS3 does not confirm this finding.

Firms in high technology sectors grow faster than firms in other sectors. In CIS2 data also firms in the knowledge intensive sectors grow faster than firms in other sectors. Process innovations alone affect the post-innovation sales growth in the CIS2 sample of innovative firms, but not in the CIS3 sample. In CIS3, the high share of employees with a tertiary level technical education affects slightly the post-innovation sales growth of firms. Export intensity does not affect the post-innovation sales growth rates of the firms: the more intensive exporters do not grow faster than the less intensive exporters.

Having controlled for the different likelihoods among firms to conduct innovative activities by Heckman probit model[5] we get a result that the post-innovation sales growth is significantly and positively associated with

I. the sales growth over the previous period (5 years)
II. the introduction of product innovation
III. the corporate spin-off of large firms
IV. the co-operation with foreign competitors when outliers except for the largest innovative firm were not eliminated (only in the CIS2 sample).

In CIS2, collaboration with American competitors affects slightly the post-innovation sales growth of these firms. There are 86 firms in the CIS2 sample collaborating with their competitors in North America after the largest innovative firm (an outlier) was eliminated from the sample. The average annual sales growth of these firms is 10.0 percent over the period 1999–2003. The number of large firms with more than 250 employees is 42 among these firms. The average annual sales growth for these large firms is 12.7 percent during the same period.

Both in the CIS2 and CIS3 samples, the co-operation with domestic consultants has a significant but negative relationship with the sales growth. It seems that innovative firms growing slower than other firms on average turn to the consultants in their innovation co-operation.

To conclude: it is significant for the longer term growth of a firm that it has introduced a product innovation or has got its birth as a spin-off for a large incumbent firm or has collaborated with foreign competitors. These firms clearly outperform other firms in their longer term sales growth.

[5] In CIS2, the Mill's ratio is significantly positive, indicating that the sample of all firms is selective in terms of likelihood to conduct innovative activities.

Table 13. Determinants of the post-innovation sales growth.

Dependent variable	Post-innovation average annual sales growth, log							
	All firms		SMEs		Inn. firms		Product innovators	
	cis2	cis3	cis2	cis3	cis2	cis3	cis2	cis3
Previous average annual sales growth, log	+++	+++	+++	+++	++	+++		+++
Number of employees, log		++		++		+++		++
Export share in sales	--	-	--	-				
Innovation output								
Product innovation	+++	+++	+++	+++	+++			
Process innovation only					+++			
R&D collaboration								
With domestic competitors								
With domestic consultants	-	---		--	-	---	--	---
With foreign competitors	+++				+++		+++	
With foreign consultants								
With domestic competitors								
With European competitors					+			
With American competitors	++				++		++	
With Japanese competitors	-				--		--	
Spin-off firms								
Spin-off of a large company	++		+		+++		+++	
Sector								
High technology								
High or medium high technology						++		
Low or medium low technology			++		+			
Low technology		-	+	--				
Knowledge intensive services					++		+++	
Other services					++		+	

Note: +++(++, +) indicates significance for the positive relationship at the 1%,(5%, 10%) level
---(--, -) indicates significance for the negative relationship at the 1%,(5%, 10%) level

5.2.3 Post-innovation growth of SMEs

We also find clear evidence that the average annual sales growth of SMEs is faster after the introduction of a product innovation compared to the sales growth of those SMEs having not introduced a product innovation. Cooperation with partner firms is found to affect employment growth directly. Results emphasize the importance of both knowledge absorption and knowledge creation to the success of innovative efforts in small firms.

Process and especially product innovations affect positively the post-innovation productivity growth (CIS3). Product innovations but not process innovations affect sales growth positively. We also confirm the finding of Klomp and van Leeuwen (2001) that innovating firms are performing better than non-innovating firms as regard to the total sales growth but the differences are less pronounced for the growth rates of employment. Also Lööf (2002) finds that innovative firms have a higher growth rate of value added, sales and profit per employee, and that employment growth is slightly larger for non-innovative firms.

5.2.4 Post-innovation growth of innovative firms and product innovators

If we only consider innovative firms in the CIS2 sample, we observe that product and process innovations affect significantly and positively the average annual sales growth over the period 1999–2003. In addition, product innovators have a much higher sales growth rate than other innovative firms in the five years period after innovation. In the CIS3 sample, we find no significant relationship between product innovation and the average sales growth over the post-innovation period 2001–2004. In other words, in the CIS3, the impact of product innovation is not distinct from that of process innovation or innovation effort only. Furthermore, if the sample includes only product innovators we cannot find any distinctive effects of new to markets innovations compared to other product innovations on longer term sales growth or demand for labour. In a shorter term these effects have been detected (Lehtoranta 2005).

It is possible that the effect of the burst of the IT-bubble and the economic slowdown in the beginning of the 21st century dominates over the positive growth impulse caused by product innovations. Second reason for this hidden relationship between innovation and average sales growth can possibly be in the increased number of business arrangements, mergers and split-ups. Third reason, which we cannot capture here, can be related to the overseas outsourcing of production and the slowdown of domestic growth over the years observed. Fourth reason may be associated with the continuous innovation activities of large firms causing at least the partial overlapping of pre-innovation and post-innovation periods.

5.2.5 Productivity growth as a factor affecting the sales growth of firms

In studies on innovation and firm performance a clear finding is that process innovations decrease production costs and that this directly results in the growth in productivity of innovative firms. In our study, the positive relationship between process innovations and productivity growth has come out as a robust result. Furthermore, among the Finnish innovative firms, the majority of them being SMEs, product innovations have a higher and a more significant impact on productivity growth than standalone process innovations. Productivity growth in the previous period, however, has a negative effect or no effect at all on the sales growth in the next period. Productivity growth is evidently more directly channelled into the sales growth of other firms or the whole industry than on the sales growth of the firms having increased their productivity.[6]

It has been argued that an increase in quality of and demand for innovative products entering the markets can increase the market share of innovating firms, which on its side may result in an increase in corporate sales growth and in labour demand. We, however, find no evidence that product innovation would be associated with an increase in the domestic market-share over the next 5 to 7 years after the introduction of innovation.[7]

5.2.6 Post-innovation productivity growth

The Heckman selection model gives a result according to which the post-innovation average annual productivity growth rate (measured as sales per employee, log index) of a firm is positively linked with

I. the productivity growth rate over the previous period
II. the size of the firm (CIS2)
III. the introduction of product innovation (CIS3 but not CIS2)
IV. the introduction of process innovation (CIS3 but not CIS2).

In CIS2, the high share of employees with a tertiary level commercial or social education has a significant and positive impact on the post-innovation productivity growth of firms. In CIS3, firms with a high share of employees with a tertiary level education have a lower productivity growth rate than other firms. This distinction is statistically significant. The previous sales growth affects negatively (CIS2) or does not affect at all (CIS3) the post-innovation productivity

[6] It should be noticed that we are here talking about productivity growth not about the high level of productivity. Usually the highly productive firms or plants are found to have a higher output growth (Nurmi 2004). An extra increase in the productivity growth rate of these frontier firms may not anymore increase the output growth of these firms compared to the non-frontier firms.

[7] The paper by Baldwin et al. (2004) finds that process innovation is related to market-share growth through its positive effect on productivity growth.

growth of the firms. The spin-offs of large firms do not stand out from other firms in their longer term productivity growth.

In CIS2, the post-innovation productivity growth rate is higher for large firms. In CIS3, product innovation has a highly significant positive relationship with the post-innovation productivity growth. This relationship does not hold in the CIS2 data, i.e. for the innovations of the years 1994–1996.

Table 14. Determinants of the post-innovation sales and productivity growth after controlling for selectivity.

Dependent variable	Post-innovation sales growth						Post-innovation productivity growth			
	All firms		SMEs		Inn. firms		All firms		SMEs	
	cis2	cis3	cis2	cis3	cis2	cis3	cis2	cis3	cis2	cis3
Previous average annual sales growth, log	+++	+++	+++	+++	++	+++	---		---	
Previous average annual prod. growth, log	--						+++	+++	+++	-
Number of employees, log							+++		++	
Export share in sales					-			-		
Innovation output										
Product innovation	+++	+++	+++	++	+++			+++		+++
Process innovation only	+				++			++		++
R&D collaboration										
With domestic competitors							--			
With domestic consultants	-	---	-	--		---		--		--
With foreign competitors	++									
With foreign consultants										
With domestic competitors		-					-			
With European competitors								-		
With American competitors	+									
With Japanese competitors	-						-			
R&D diversity	-						--		-	
Share of highly educated employees										
Technical education		+						---		---
Commercial or social education							++		++	
Other education						+	+	-		
Spin-off of a large company	++		++		+++					
Sector										
High technology				++			++			
High or medium high technology				++		++	+			
Low or medium low technology	+			+	+++	+		--		
Low technology					++			---		
Knowledge intensive services				++	+++					
Other services	++		+				--	-		-
Millsratio							+++			

Note: +++(++, +) indicates significance for the positive relationship at the 1%,(5%, 10%) level
---(--, -) indicates significance for the negative relationship at the 1%,(5%, 10%) level

5.2.7 Post-innovation growth in labour demand

The analysis of the longer term labour demand by firms tells us what the growth analyses of the sales and labour productivity already have suggested. The post-innovation growth in labour demand is positively linked with the

I. growth in labour demand in the previous period
II. growth in sales in the previous period (CIS2 but not CIS3)
III. the introduction of product innovation (CIS2 but not CIS3)
IV. the high share of employees with tertiary education in technical fields (CIS3)
V. innovation collaboration with foreign competitors (CIS3).

In the CIS3 sample, the significant positive relationship between the labour demand of SMEs and the innovation collaboration with research institutes comes out. CIS3 linked with the production panel do not give any significant relationship between product or process innovation and the post-innovation labour demand, when only innovative firms are considered. The potential reasons for this may emerge from the macroeconomic factors or reorganizations that were discussed in the context of sales growth.

5.2.8 A basic version of the CDM model

In this chapter we consider the results of a basic version of the CDM model based on four steps: the Heckman selection equation, innovation input equation, innovation output equation and productivity equation. The Heckman selection model is estimated on full samples of the CIS2 and CIS3 by using firm level data on firm size, belonging to a group of firms, the share of export in sales, past domestic, EPO and US patenting activities, share of highly educated employees with technical education, commercial and social education or with other education. Sector dummies are created for high technology industries, high-medium technology industries, low-medium technology industries, low technology industries, knowledge intensive services and other services. Industries outside these fields are used as reference.

In the CIS samples, which are not pure random samples, the probability to be an innovative firm is significantly and positively affected by the size of the firm, the export share in sales, past domestic patenting behaviour measured with the number of domestic patent applications and the share of highly educated employees. The likelihood of the decision to innovate and to be included in the sample has to be taken into account when estimating which factors affect the innovation input. This is done with the Heckman probit model.

According to the innovation input equation, the size of innovation efforts measured as the amount of innovation expenditures per employee in year t+3 (the last year in the reference period) and controlled for the selectivity is significantly and positively affected by the export share in sales in year t+3, collaboration in innovation, introducing a product innovation (in CIS2) and being a continuous R&D performer within the reference period. Also getting public R&D funding in year t+3 affects the innovation input highly significantly. In the CIS, only innovative firms have been asked to report their collaboration in innovation. It follows from this that collaboration cannot be used as a determinant of innovativeness. Nevertheless, it can be used as a determinant of R&D investment levels or innovation expenditure levels. It can also be used as a determinant of innovation output, especially if the effects of different types of partners are being considered.

In the third step, innovation output measured with the amount of innovative sales per employee in year t+3 is explained with the innovation expenditures in t+3, product innovation, process innovation, belonging to the group of firms, firm size and collaboration in innovation over the whole period. We differentiate here between six types of partners: competitors, customers, suppliers, consultants, universities and research institutes. Since the model is estimated only on innovative firms, the estimation technique controls for selectivity. In addition, it controls for potential endogeneity, which might arise because innovation surveys ask for innovation inputs and output in the same year.

Innovation expenditures and a binary variable describing product innovation and respectively process innovation (in CIS2) affect innovative sales significantly and positively. Collaboration with suppliers affects innovation output negatively (CIS2) and collaboration with competitors positively (CIS3) with a 5% significance level. The same finding concerning collaboration with competitors was detected by e.g. Lööf and Heshmati (2002) and Belderbos et al. (2004). If we make a distinction between overseas and domestic collaboration we find that it is collaboration with overseas competitors and own group that affects the innovation output, and more specifically the collaboration with competitors in the US.

In the final step, the level of labour productivity measured with sales per employee in year t+3 is related to innovation output in t+3, the share of highly educated in t+3 and product and process innovation over the whole reference period (t+1, t+3). Again, selectivity and potential endogeneity are dealt with by appropriate econometric techniques. Collaboration with different partners is not used as explanatory variable here, although incoming knowledge flows due to (overseas) collaboration may well have their own direct impact on productivity (Belderbos et al. 2004), not captured by the introduction of technological product or process innovation or by innovative sales accounted for by product innovations. The binary variable for spin-off firms describing the corporate spin-offs identified in a separate survey is added here trying to capture the technology and organizational expertise of these firms based on their parent relationship.

We get a result that innovation output, enterprise group, the share of employees with commercial or other tertiary education affect productivity level significantly and positively. The introduction of a product innovation − and respectively of a process innovation in CIS2 − affects productivity level in year t+3 negatively compared to firms that have no innovation but only innovation projects during the reference period.[8] The relative productivity gains of innovations will emerge not in the reference period but rather in the post-innovation period, as we have found earlier in this study.

Involving the dichotomous variables for both product and process innovations significantly improves the explanatory power of the productivity equation. Being established as a spin-off firm does not have any effect on productivity level compared to other innovative firms. This finding confirms the results got in the single equation regressions with Heckman selection, and is partly explained by the fact that all innovation active spin-offs within industries covered by the CIS samples are not known and in many cases more than 5 years has gone since the birth of these firms.

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[8] Firms that have introduced an innovation or have abandoned or ongoing innovation projects during the reference period have been defined to be innovative here.

Table 15. Multi-step production function model.

	Step 1: Selection equation					
	CIS2			CIS3		
Dependent variable	Coef.		Std. Err.	Coef.		Std. Err.
The probability to be an innovative firm						
Firm size	0,261	***	0,027	0,298	***	0,288
Enterprise group	-0,002		0,074	-0,127	*	0,074
Export share	0,892	***	0,131	0,297	**	0,125
Past domestic patenting	0,354	***	0,118	0,391	***	0,111
Past EPO patenting	0,214		0,221	-0,056		0,162
Past US patenting	-0,180		0,235	-0,223		0,198
Share of highly educated employees						
Technical education	1,409	**	0,705	1,292		0,873
Commercial or social education	0,068		0,291	0,510	*	0,267
Other education	0,353	*	0,203	0,495	**	0,195
Sector						
High technology	0,777	***	0,187	0,573	**	0,255
High-medium technology	0,407	***	0,093	0,405	***	0,102
Low-medium technology	0,193	**	0,097	0,160	*	0,097
Knowledge intensive services	0,503	***	0,150	0,135		0,127
Other services	-0,268	***	0,101	-0,213	*	0,111
Constant	-1,662	***	0,122	-1,368	***	0,131

	Step 2: Innovation input equation					
	CIS2			CIS3		
Dependent variable	Coef.		Std. Err.	Coef.		Std. Err.
Innovation expenditures per employee, log						
Enterprise group	0,035		0,113	-0,092		0,103
Export share	0,834	***	0,191	0,544	**	0,157
Collaboration	0,251	**	0,111	0,326	**	0,102
Product innovation	0,354	***	0,116	0,037		0,114
Process innovation	0,106		0,110	0,050		0,094
Continuous R&D	1,090	***	0,114	0,827	***	0,111
Public funding for R&D	0,687	***	0,112	0,590	***	0,101
Sector						
High technology	1,198	***	0,240	1,602	***	0,291
High-medium technology	0,795	***	0,142	0,876	***	0,147
Low-medium technology	0,106		0,154	0,234		0,146
Knowledge intensive services	1,051	***	0,205	0,735	***	0,156
Other services	0,001		0,204	0,264		0,189
Constant	0,001		0,265	-1,132	***	0,230
Number of observations	1895			1614		
Censored observations	1121			696		
Uncensored observations	774			918		
Log likelihood	-2362,9			-2566,1		

Table 15. Multi-step production function model (continued).

	Step 3: Innovation output equation			
	CIS2		CIS3	
Dependent variable	Coef.	Std. Err.	Coef.	Std. Err.
Innovative sales per employee, log				
Firm size	0,017	0,074	-0,033	0,079
Enterprise group	0,069	0,133	0,205 *	0,122
Product innovation	2,439 ***	0,126	2,805 ***	0,095
Process innovation	0,528 ***	0,142	0,178	0,114
Innovation expenditures per employee	0,157 ***	0,041	0,231 ***	0,039
Mills ratio	-0,089	0,317	-0,095	0,460
Collaboration with competitors	-0,001	0,162	0,163 **	0,064
Collaboration with customers	-0,055	0,147	0,112	0,122
Collaboration with consultants	0,043	0,157	0,017	0,059
Collaboration with suppliers	-0,298 **	0,143	0,094 *	0,052
Collaboration with universities	0,176	0,168	0,031	0,059
Collaboration with research institutes	0,151	0,163	0,054	0,110
Sector				
High technology	0,858 ***	0,332	0,223	0,346
High-medium technology	0,821 ***	0,206	0,437 **	0,182
Low-medium technology	0,404 **	0,186	0,075	0,157
Knowledge intensive services	-2,032 ***	0,228	-0,144	0,176
Other services	-1,556 ***	0,233	0,458 *	0,255
Constant	-0,553	0,614	-0,726	0,637
Number of observations	774		553	
R squared	0,548		0,540	
	Step 4. Productivity equation			
	CIS2		CIS3	
Dependent variable	Coef.	Std. Err.	Coef.	Std. Err.
Labour productivity, log				
Firm size	0,018	0,420	0,046	0,052
Enterprise group	0,292 ***	0,080	0,307 ***	0,074
Product innovation	-0,999 ***	0,363	-0,676 **	0,278
Process innovation	-0,294 ***	0,104	0,007	0,067
Innovative sales per employee, log	0,401 ***	0,143	0,243 ***	0,092
Spin-off firm	0,454	0,303	0,327	0,228
Mills ratio	-0,060	0,189	-0,063	0,332
Share of highly educated employees				
Technical education	-0,961 *	0,516	-1,404	1,211
Commercial or social education	1,690 ***	0,333	1,027 ***	0,363
Other education	0,318	0,268	0,751 ***	0,210
Sector				
High technology	-0,692 ***	0,221	-0,547 ***	0,169
High-medium technology	-0,559 ***	0,173	-0,304 **	0,121
Low-medium technology	-0,340 ***	0,118	-0,259 ***	0,094
Knowledge intensive services	0,219	0,364	-0,885 ***	0,119
Other services	0,706 **	0,293	0,105	0,188
Constant	6,467 ***	0,375	4,618 ***	0,484
Number of observations	774		553	
R squared	.		0,417	

5.2.9 Summary of results

Process innovation

We obtained evidence that process innovations affect the post-innovation total sales growth positively among innovative firms, but only in the CIS2 sample, which includes relatively more innovative SMEs than the CIS3 sample. Among SMEs as well as in the full sample including both innovative and non-innovative firms, process innovations have no clear effect on the longer term sales growth. Our **hypothesis 1**, stating that process innovations are expected to have a significant and positive effect on turnover growth, receives therefore only partial support.

In studies on innovation and firm performance a clear finding is that process innovations decrease production costs and that this directly results in the growth in productivity of innovative firms. In our study, the positive relationship between process innovations and productivity growth has come out as a robust result.

In a CDM model, a binary variable describing process innovation affects innovative sales positively, but only in the CIS2 sample. Furthermore, in the CIS2 sample, the introduction of a process innovation affects productivity level negatively. Involving the dichotomous variables for both product and process innovations significantly improves the explanatory power of the productivity equation based on innovative firms not necessary having non-zero innovation expenditures or innovative sales.

Product innovation

We get evidence that product innovations affect total sales growth positively among innovative firms, but only in the CIS2 sample. Product innovators have a much higher sales growth rate than other innovative firms in the five years period after innovation. Also among SMEs as well as in the full sample including both innovative and non-innovative firms, the effect of product innovation on the total sales growth is highly significant and positive for both CIS2 and CIS3 samples. This at least partly supports our **hypothesis 2**, stating that product innovations affects positively the total sales growth of innovative firms. We also confirm the finding of Klomp and van Leeuwen (2001) that innovating firms are performing better than non-innovating firms as regard to the total sales growth. This supports our **hypothesis 3**, stating that the sales growth of product innovators is faster than the sales growth of non-innovative firms. We also confirm the finding of Klomp and van Leeuwen that the differences in the growth rates of employment are less pronounced. The CIS3 sample linked with the business register does not give any significant relationship between product or process innovation and the post-innovation labour demand, when only innovation active firms are considered.

When studying the post-innovation productivity growth, we get clear evidence that the effect of product innovation on productivity growth is highly significant and positive among innovative firms. Among innovative firms, product innovations have a higher and a more significant impact on productivity growth than process innovations. Among SMEs and in the full sample this holds only for the CIS3 firms.

By using a CDM model variant we get a result that a binary variable describing product innovation affects innovative sales positively. In the productivity equation, the introduction of a product innovation affects productivity level negatively, although innovative sales have a highly significant and positive relationship with the level of productivity. The productivity level of firms having innovation projects or standalone process innovations is higher than that of product innovators.

Collaboration in innovation

The collaboration with foreign competitors affects the total sales growth positively, but only in the CIS2 sample. Among SMEs, collaboration with partner firms is found to affect employment growth positively. In the CIS3 sample, the significant positive relationship between the labour demand of SMEs and the innovation collaboration with research institutes comes out. These findings at least partly support our **hypothesis 4**, stating that collaboration in innovation affects the growth performance of firms directly.

A CDM model variant gives a result that collaboration with competitors affects innovation output positively, but only in the CIS3 sample. If we make a distinction between overseas and domestic collaboration we find that it is collaboration with overseas competitors and own group that affects the innovation output, and more specifically the collaboration with competitors in the US. The same finding concerning collaboration with competitors was detected by e.g.

Lööf and Heshmati (2002) and Belderbos et al. (2004). In a CDM model, collaboration with different partners is not used as explanatory variable in the productivity equation, although incoming knowledge flows due to close-to-market collaboration may well have their own direct impact on productivity (Belderbos et al. 2004), not captured by the introduction of technological product or process innovation or by innovative sales accounted for by product innovations.

Spin-off firms

We get a result that the corporate spin-offs of large firms affect the longer term sales growth and productivity growth positively, but only in the CIS2 sample. This relationship holds in the sample of innovative firms, as well as in the full sample and the sample of SMEs. This supports at least partly our **hypothesis 5**, stating that spin-offs of large firms have a higher growth performance than other firms. The insignificant effect of spin-offs on the growth performance of CIS3 firms is at least partly explained by the fact that all innovative spin-offs within industries covered by the CIS samples are not known and in many cases more than 5 years was gone since the birth of these firms. In addition, the share of small firms and spin-offs is lower in the CIS3 sample than in the CIS2 sample.

In contrast to sales growth and productivity growth, productivity levels are not affected by spin-offs among innovative firms for both the CIS2 and CIS3 samples. This result is based on a CDM model variant.

Previous performance

We get clear evidence that previous sales growth affect positively the future innovation activities of the firms. Also past patenting activities affect positively the probability to be an innovative firm. Previous sales growth also affects the post-innovation sales growth positively.

The previous sales growth affects negatively (CIS2) or does not affect at all (CIS3) the post-innovation productivity growth of the firms. Similarly, productivity growth in the previous period has a negative effect or no effect at all on the sales growth in the next period.

Highly educated employees

The high share of employees with university level technical education has a positive impact on innovation activities of firms. Also in a CDM-model variant, the share of highly educated employees affects the probability to be an innovative firm. In addition, the share of employees with commercial or other tertiary education affects productivity level positively.

In CIS2, the high share of employees with a tertiary level commercial or social education has a significant and positive impact on the post-innovation productivity growth of firms. In CIS3, firms with a high share of employees with a tertiary level education have a lower productivity growth rate than other firms.

5.3 Conclusions

Numerous empirical studies have confirmed the importance of market demand for a firm's innovative activities and corporate growth. The introduction of product innovation normally results in a new demand, and the introduction of process innovation in a reduction of costs. An increase in quality of and demand for innovative products entering the markets can increase the market share of innovating firms, which on its side may result in an increase in sales growth and in labour demand.

In this study we have investigated the determinants of longer term corporate growth, measured with average annual total sales growth, employment growth and productivity growth over periods related to innovation. This approach is reasoned especially for small firms and new entrants which have introduced their first major innovation within the reference period. It is also justified for other firms that are renewing their products and processes. The fruits of this renewing process typically show up in periods related to the product cycles of the firm. We can therefore speak about pre-innovation, innovation and post-innovation periods related to the major innovations of the firms. These periods are recurrent and cyclical but not anymore as clear-cut as they used to be in the advent of new information and communication technologies.

As shown in Figure 1, innovation output (innovation occurrence or innovative sales) may contribute to the post-innovation total sales growth through productivity growth, increase in the market share or market expansion. Many studies indeed confirm the positive relationship between innovation output and productivity growth. Process innovation typically results in a cost reduction, change in relative prises or increase in the quality of products affecting possibly the market shares. Radical innovation for its part may open up totally new markets and lead to market and corporate expansion. The post-innovation total sales growth, however, is determined by many other factors than innovation only.

We get only partial evidence that process and product innovations affect significantly and positively the post-innovation total sales growth among innovative firms. Similarly we get only partial evidence that collaboration in innovation with foreign competitors and being established as spin-offs of large firms affects the total sales growth. However, in our study, the positive relationship between the occurrence of innovations, both product and process innovations, and productivity growth has come out as a robust result. If we also include non-innovative firms in the samples, we get a robust result that product innovation but not process innovation contributes positively to the total sales growth. A binary variable for corporate spin-off firms identified in a separate survey is added here trying to capture the technology and organizational expertise of these firms based on their parent relationship.

Based on the results derived either from the CIS2 or CIS3 samples, we can conclude, that it is significant for the longer term post-innovation sales growth of a firm that it has introduced a product innovation or has got its birth as a spin-off of a large firm or has collaborated with foreign competitors. These firms clearly outperform other firms in their longer term sales growth.

In the CIS3 sample of innovative firms, we find no significant relationship between product innovation and the average sales growth over the post-innovation period 2001–2004. It is possible that the effect of the burst of the IT-bubble and the economic slowdown in the beginning of the 21st century dominates over the positive growth impulse caused by product innovations. A second reason for this hidden relationship between innovation and average sales growth among innovative firms can possibly be in the increased number of business arrangements, mergers and split-ups. Third reason, which we cannot capture here, can be related to the offshoring of production and the slowdown of domestic growth over the years observed. Fourth reason may be associated with the continuous innovation activities of large firms causing at least the partial overlapping of pre-innovation and post-innovation periods.

An interesting finding, which should be investigated more deeply, is that productivity growth in the previous period has a negative effect or no effect at all on the sales growth in the next period. Could it be so that productivity growth is more directly channelled into the sales growth of other firms or the whole industry than on the sales growth of the firms having increased their productivity? It is also important to note that what we refer here as firms in many cases are legal units of larger groups of enterprises, and these groups can transfer activities between these units, also between domestic and foreign units.

In this study we moved from the full CIS samples to small and medium-sized firms, to innovative firms and finally to product innovators. In each sub-samples different micro and macro relationships are emerging. The conclusions on the determinants of longer term sales, employment and productivity growth are very much dependent on the sub-samples, the time periods and the growth factors we are focusing on. The determinants of the growth performance of firms are in other words very much state- and time-dependent.

Similar results are found in many other studies on the determinants of the corporate growth. These determinants can be idiosyncratic, specific to each firm or groups of firms and no group of factors can be shown to be pervasive or ubiquitous drivers for the growth performance. The question is also about how broad a brush we are using. If we reduce the relationship between the determinants and the growth performance of (young) firms enough, we can get stylized facts that are broad or pervasive enough. It follows from this that regression models often reveal only quite broad or reduced consistent relations, which sometimes are called foreseeable or trivial results. As an example of interesting, but not of surprising result we can mention a finding based on the Canadian firm level data that a novel market or novel technology affects the growth of firms more than their innovation activities in general or the training of personnel or networking. It is another thing how consistent or time independent these findings are. In this study, we found, for example, that spin-offs have a significant and positive influence on the average annual sales growth rates over the five years post-innovation period both for innovative firms and for the full sample and SMEs, meaning that innovations do not dominate over the expertise effects of spin-offs. This positive relationship between spin-offs and the growth performance of firms holds in the CIS2 sample including small start-ups and spin-offs relatively more than the CIS3 sample.

Table 16. Summary.

In this study we have investigated the determinants of longer term corporate growth, measured with average annual total sales growth, employment growth and productivity growth over periods related to innovation. This approach is reasoned especially for small firms and new entrants which have introduced their first major innovation within the reference period. It is also justified for other firms that are renewing their products and processes. The fruits of this renewing process typically show up in periods related to the product cycles of the firm. We get only partial evidence that process and product innovations affect significantly and positively the post-innovation total sales growth among innovation active firms. Similarly we get only partial evidence that collaboration in innovation with foreign competitors and being established as spin-offs of large firms affects the total sales growth. The positive relationship between the occurrence of innovations and the future productivity growth comes out as a robust result. If we also include non-innovative firms in the samples, we get a robust result that product innovation but not process innovation contributes positively to the total sales growth. A binary variable for corporate spin-off firms identified in a separate survey is added here trying to capture the technology and organizational expertise of these firms based on their parent relationship. We can conclude, that it is significant for the longer term post-innovation sales growth of a firm that it has introduced a product innovation or has got its birth as a spin-off of a large firm or has collaborated with foreign competitors. These firms clearly outperform other firms in their longer term sales growth. An interesting finding, that should be investigated more deeply, is that productivity growth in the previous period has a negative effect or no effect at all on the sales growth in the next period. Furthermore, we find that spin-offs have a significant and positive influence on the average annual sales growth rates over the five years post-innovation period both for innovative firms and for the full sample and SMEs. This positive relationship between spin-offs and the growth performance of firms holds in the CIS2 sample including small start-ups and spin-offs relatively more than the CIS3 sample. In our variant of the CDM model, the binary indicator variables for product and process innovations in the productivity equation are supposed to capture those effects of innovations on the level of productivity not captured by innovative sales per employee. It follows from this that their coefficients are significantly negative.

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Appendix A

Table A1. Determinants of innovative activities in the full sample.

CIS2	**All firms**					
Dependent variable	**Model 1**			**Model 2**		
Innovation activities 1994–1996, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1989–1994, log				0,307	**	0,136
Number of employees 1996, log	0,218	***	0,025	0,234	***	0,028
Export share in sales 1996	0,930	***	0,132			
Productivity 1996						
Labour productivity, log	0,066		0,043	0,062		0,049
Patenting 1985–1993						
Domestic applications, dummy	0,348	***	0,123	0,512	***	0,130
EPO applications, dummy	0,341		0,224	0,444	*	0,232
US granted patents, dummy	-0,157		0,242	-0,148		0,249
Share of highly educated employees 1996						
Technical education	2,071	***	0,723	2,144	***	0,858
Commercial or social education	0,260		0,294	0,129		0,324
Other education	0,593	***	0,201	0,675	***	0,231
Sector						
High technology	0,782	***	0,248	0,741	***	0,280
High or medium high technology	0,428	**	0,184	0,425	**	0,215
Low or medium low technology	0,240		0,187	0,197		0,218
Low technology	0,049		0,182	0,067		0,212
Knowledge intensive services	0,429	**	0,214	0,487	*	0,250
Other services	-0,288		0,180	-0,304		0,212
Intercept	-2,023	***	0,358	-1,987	***	0,405
Number of observations	1896			1533		
Log likelihood	-1056,421			-871,301		
Pseudo R2	0,176			0,153		
CIS3	**All firms**					
Dependent variable	**Model 1**			**Model 2**		
Innovation activities 1998–2000, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1991–1996, log				0,581	***	0,148
Number of employees 2000, log	0,208	***	0,028	0,211	***	0,032
Export share in sales 2000	0,180		0,133			
Productivity 2000						
Labour productivity, log	0,175	***	0,039	0,211	***	0,046
Patenting 1985–1997						
Domestic applications, dummy	0,481	***	0,116	0,579	***	0,126
EPO applications, dummy	0,016		0,169	-0,085		0,189
US granted patents, dummy	-0,192		0,207	-0,109		0,221
Share of highly educated employees 2000						
Technical education	2,812	***	0,875	2,580	**	1,033
Commercial or social education	0,260		0,285	0,434		0,320
Other education	0,583	***	0,202	0,573	**	0,247
Sector						
High technology	0,916	***	0,304	1,308	***	0,367
High or medium high technology	0,692	***	0,178	0,662	***	0,195
Low or medium low technology	0,487	***	0,174	0,504	***	0,193
Low technology	0,341	**	0,172	0,443	**	0,190
Knowledge intensive services	0,394	**	0,185	0,378	*	0,215
Other services	0,007		0,174	-0,069		0,196
Intercept	-2,180	***	0,268	-2,485	***	0,315
Number of observations	1614			1274		
Log likelihood	-967,142			-749,864		
Pseudo R2	0,124			0,145		

Table A2. Determinants of innovative activities among SMEs.

CIS2 Dependent variable Innovation activities 1994–1996, dummy	SMEs Model 1 Coef.	Sig.	Std. Err.	Model 2 Coef.	Sig.	Std. Err.
Average annual sales growth 1989–1994, log				0,256	*	0,143
Number of employees 1996, log	0,152	***	0,033	0,145	***	0,037
Export share in sales 1996	0,892	***	0,142	0,855	***	0,158
Productivity 1996						
Labour productivity, log	0,052		0,048	0,032		0,054
Patenting 1985–1993						
Domestic applications, dummy	0,367	***	0,141	0,438	***	0,151
EPO applications, dummy	0,186		0,261	0,216		0,285
US granted patents, dummy	-0,173		0,296	-0,147		0,318
Share of highly educated employees 1996						
Technical education	2,795	***	0,823	2,000	**	0,891
Commercial or social education	0,419		0,312	0,386		0,350
Other education	0,508	**	0,207	0,389		0,243
Sector						
High technology	0,670	**	0,268	0,451		0,304
High or medium high technology	0,393	**	0,198	0,156		0,234
Low or medium low technology	0,195		0,200	-0,074		0,236
Low technology	0,043		0,197	-0,168		0,231
Knowledge intensive services	0,492	**	0,229	0,476	*	0,269
Other services	-0,259		0,195	-0,394	*	0,230
Intercept	-1,724	***	0,395	-1,398	***	0,455
Number of observations	1647			1348		
Log likelihood	-945,996			769,531		
Pseudo R2	0,117			0,117		
CIS3 Dependent variable Innovation activities 1998–2000, dummy	**SMEs Model 1 Coef.**	**Sig.**	**Std. Err.**	**Model 2 Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1991–1996, log				0,609	***	0,157
Number of employees 2000, log	0,181	***	0,041	0,197	***	0,047
Export share in sales 2000	0,115		0,142	-0,021		0,165
Productivity 2000						
Labour productivity, log	0,166	***	0,043	0,214	***	0,052
Patenting 1985–1997						
Domestic applications, dummy	0,576	***	0,127	0,676	***	0,138
EPO applications, dummy	-0,150		0,186	-0,252		0,205
US granted patents, dummy	-0,478	**	0,237	-0,427	*	0,253
Share of highly educated employees 2000						
Technical education	3,274	***	0,956	2,872	***	1,101
Commercial or social education	0,459		0,305	0,629	*	0,342
Other education	0,536	**	0,211	0,541	**	0,257
Sector						
High technology	1,475	***	0,391	1,708	***	0,445
High or medium high technology	0,775	***	0,193	0,768	***	0,221
Low or medium low technology	0,578	***	0,189	0,597	***	0,217
Low technology	0,437	**	0,188	0,540	**	0,216
Knowledge intensive services	0,513	**	0,203	0,503	**	0,235
Other services	0,217		0,191	0,155		0,217
Intercept	-2,153	***	0,304	-2,588	***	0,364
Number of observations	1379			1099		
Log likelihood	-866,596			-673,272		
Pseudo R2	0,091			0,116		

Table A3. Determinants of product innovators in the full sample.

CIS2	**All firms**					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1994–1996, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1989–1994, log				0,264	*	0,145
Number of employees 1996, log	0,189	***	0,026	0,171	***	0,030
Export share in sales 1996	0,858	***	0,130	0,864	***	0,146
Productivity 1996						
Labour productivity, log	0,025		0,045	0,015		0,052
Patenting 1985–1993						
Domestic applications, dummy	0,289	**	0,118	0,350	***	0,130
EPO applications, dummy	0,447	**	0,204	0,515	**	0,218
US granted patents, dummy	-0,004		0,222	-0,004		0,236
Share of highly educated employees 1996						
Technical education	1,950	***	0,698	2,112	**	0,829
Commercial or social education	0,327		0,308	0,249		0,346
Other education	0,517	**	0,203	0,446	*	0,239
Sector						
High technology	0,509	**	0,251	0,313		0,288
High or medium high technology	0,405	**	0,194	0,232		0,230
Low or medium low technology	0,021		0,199	-0,189		0,236
Low technology	-0,218		0,193	-0,326		0,228
Knowledge intensive services	0,524	**	0,221	0,567	**	0,260
Other services	-0,173		0,192	-0,235		0,226
Intercept	-1,905	***	0,373	-1,692	***	0,428
Number of observations	1896			1533		
Log likelihood	-948,199			-751,166		
Pseudo R2	0,178			0,183		
CIS3	**All firms**					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1998–2000, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1991–1996, log				0,509	***	0,139
Number of employees 2000, log	0,175	***	0,027	0,173	***	0,031
Export share in sales 2000	-0,028		0,129	-0,139		0,149
Productivity 2000						
EPO applications, dummy	0,184		0,154	0,094		0,173
US granted patents, dummy	-0,138		0,184	-0,053		0,199
Share of highly educated employees 2000						
Technical education	1,138		0,761	1,959	**	0,979
Commercial or social education	0,420		0,282	0,562	*	0,319
Other education	0,417	**	0,199	0,307		0,245
Sector						
High technology	0,986	***	0,282	1,150	***	0,320
High or medium high technology	0,960	***	0,184	0,988	***	0,214
Low or medium low technology	0,648	***	0,182	0,754	***	0,211
Low technology	0,460	**	0,180	0,604	***	0,210
Knowledge intensive services	0,772	***	0,192	0,767	***	0,227
Other services	0,293		0,183	0,262		0,211
Intercept	-2,385	***	0,273	-2,638	***	0,325
Number of observations	1614			1274		
Log likelihood	-993,289			-764,960		
Pseudo R2	0,106			0,106		

Table A4. Determinants of product innovators among SMEs.

CIS2	SMEs					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1994–1996, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1989–1994, log				0,302	**	0,150
Number of employees 1996, log	0,101	***	0,035	0,100	**	0,040
Export share in sales 1996	0,914	***	0,145	0,854	***	0,162
Productivity 1996						
Labour productivity, log	0,029		0,051	0,018		0,058
Patenting 1985–1993						
Domestic applications, dummy	0,334	**	0,142	0,449	***	0,152
EPO applications, dummy	0,369		0,252	0,346		0,277
US granted patents, dummy	-0,172		0,292	-0,190		0,315
Share of highly educated employees 1996						
Technical education	2,301	***	0,774	1,846	**	0,857
Commercial or social education	0,458		0,331	0,366		0,376
Other education	0,377	*	0,211	0,307		0,249
Sector						
High technology	0,398		0,279	0,218		0,318
High or medium high technology	0,338		0,210	0,167		0,248
Low or medium low technology	-0,091		0,215	-0,299		0,254
Low technology	-0,293		0,212	-0,421	*	0,249
Knowledge intensive services	0,558	**	0,238	0,597	**	0,280
Other services	-0,182		0,207	-0,269		0,245
Intercept	-1,599	***	0,418	-1,416	***	0,482
Number of observations	1647			1348		
Log likelihood	-805,709			-648,546		
Pseudo R2	0,127			0,137		
CIS3	**SMEs**					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1998–2000, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1991–1996, log				0,511	***	0,151
Number of employees 2000, log	0,142	***	0,040	0,148	***	0,046
Export share in sales 2000	-0,074		0,141	-0,194		0,164
Productivity 2000						
Labour productivity, log	0,139	***	0,043	0,172	***	0,052
Patenting 1985–1997						
Domestic applications, dummy	0,422	***	0,117	0,510	***	0,128
EPO applications, dummy	0,004		0,174	-0,052		0,192
US granted patents, dummy	-0,405	*	0,224	-0,412	*	0,239
Share of highly educated employees 2000						
Technical education	1,331	*	0,798	2,186	**	1,033
Commercial or social education	0,580	*	0,307	0,742	**	0,345
Other education	0,448	**	0,208	0,326		0,255
Sector						
High technology	1,175	***	0,339	1,293	***	0,372
High or medium high technology	0,945	***	0,203	1,014	***	0,237
Low or medium low technology	0,647	***	0,200	0,743	***	0,233
Low technology	0,417	**	0,200	0,548	**	0,234
Knowledge intensive services	0,748	***	0,213	0,765	***	0,250
Other services	0,410	**	0,203	0,386		0,234
Intercept	-2,223	***	0,311	-2,571	***	0,375
Number of observations	1379			1099		
Log likelihood	-867,411			-671,614		
Pseudo R2	0,072			0,092		

Table A5. Determinants of product innovators among innovative firms.

CIS2	Innovative firms					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1994–1996, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1989–1994, log				0,132		0,220
Number of employees 1996, log	0,084	**	0,035	0,086	**	0,041
Export share in sales 1996	0,485	***	0,179	0,577	***	0,205
Productivity 1996						
Labour productivity, log	0,008		0,073	0,023		0,082
Patenting 1985–1993						
Domestic applications, dummy						
EPO applications, dummy						
US granted patents, dummy						
Share of highly educated employees 1996						
Technical education						
Commercial or social education						
Other education						
Sector						
High technology	0,060		0,360	-0,047		0,411
High or medium high technology	0,301		0,309	0,276		0,360
Low or medium low technology	-0,242		0,312	-0,315		0,366
Low technology	-0,499		0,305	-0,483		0,356
Knowledge intensive services	0,672	**	0,340	0,780	**	0,402
Other services	0,318		0,323	0,283		0,370
Intercept	0,057		0,607	-0,059		0,694
Number of observations	775			605		
Log likelihood	-418,388			-323,822		
Pseudo R2	0,080			0,087		
CIS3	**Innovative firms**					
Dependent variable	**Model 1**			**Model 2**		
Product innovations 1998–2000, dummy	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1991–1996, log				0,108		0,189
Number of employees 2000, log	0,084	**	0,035	0,087	**	0,041
Export share in sales 2000	-0,253		0,170	-0,318		0,196
Productivity 2000						
Labour productivity, log	0,039		0,058	0,028		0,071
Patenting 1985–1997						
Domestic applications, dummy						
EPO applications, dummy						
US granted patents, dummy						
Share of highly educated employees 2000						
Technical education						
Commercial or social education						
Other education						
Sector						
High technology	0,775	**	0,349	0,845	**	0,375
High or medium high technology	0,983	***	0,252	1,139	***	0,288
Low or medium low technology	0,614	**	0,248	0,841	***	0,282
Low technology	0,413	**	0,244	0,584	**	0,277
Knowledge intensive services	1,005	***	0,262	1,026	***	0,300
Other services	0,706	***	0,267	0,759	**	0,299
Intercept	-0,356		0,397	-0,433		0,475
Number of observations	918			699		
Log likelihood	-452,219			-344,535		
Pseudo R2	0,039			0,038		

Table A6. Determinants of innovative sales among innovative firms.

CIS2 Dependent variable Share of innovative sales 1996	Innovative firms Model 1 Coef.	Sig.	Std. Err.	Model 2 Coef.	Sig.	Std. Err.
Average annual sales growth 1989–1994, log				0,032		0,026
Number of employees 1996, log	-0,008	*	0,004	-0,010	**	0,004
Export share in sales 1996	0,005		0,022	0,010		0,023
Productivity 1996						
Labour productivity, log	-0,011		0,009	-0,004		0,010
Patenting 1985–1993						
Domestic applications, dummy	0,000		0,019			
EPO applications, dummy	0,037		0,027			
US granted patents, dummy	-0,071	**	0,029			
R&D intensity 1996	0,325	***	0,073	0,382	***	0,072
Sector						
High technology	0,189	***	0,048	0,191	***	0,049
High or medium high technology	0,133	***	0,041	0,125	***	0,043
Low or medium low technology	0,119	***	0,042	0,097	**	0,045
Low technology	0,087	**	0,042	0,096	**	0,044
Knowledge intensive services	-0,041		0,043	-0,036		0,045
Other services	-0,013		0,043	-0,009		0,045
Intercept	0,119		0,078	0,068		0,081
Number of observations	563			440		
Log likelihood	271,614			248,226		
Pseudo R2						
CIS3 **Dependent variable** **Share of innovative sales 2000**	**Innovative firms** **Model 1** **Coef.**	**Sig.**	**Std. Err.**	**Model 2** **Coef.**		**Std. Err.**
Average annual sales growth 1991–1996, log				0,066	**	0,029
Number of employees 2000, log	-0,012	*	0,006	-0,009		0,007
Export share in sales 2000	0,052		0,031	0,053		0,034
Productivity 2000						
Labour productivity, log	-0,005		0,012	-0,001		0,013
Patenting 1985–1997						
Domestic applications, dummy	-0,003		0,024			
EPO applications, dummy	-0,070	**	0,031			
US granted patents, dummy	0,029		0,036			
R&D intensity 2000	0,539	***	0,079	0,404	***	0,099
Sector						
High technology	0,250	***	0,070	0,255	***	0,075
High or medium high technology	0,100	*	0,055	0,076		0,062
Low or medium low technology	0,063		0,056	0,064		0,062
Low technology	0,039		0,055	0,031		0,063
Knowledge intensive services	0,071		0,056	0,091		0,064
Other services	0,089		0,057	0,096		0,065
Intercept	0,197	**	0,084	0,140		0,093
Number of observations	726			553		
Log likelihood	56,503			68,168		
Pseudo R2						

Table A7. Heckman selection models for the post-innovation sales growth in the full sample of CIS2.

CIS2	**All without outliers**					
Dependent variable	**Model 1**			**Model 2**		
Average annual sales growth 1998–2003, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1994–1998, log	0,062	***	0,017	0,063	***	0,017
Average annual productivity growth 1994–1998, log	0,026		0,022	0,026		0,023
Number of employees 1996, log	-0,008		0,006	-0,008		0,006
Export share in sales 1996	-0,055	**	0,024	-0,053	**	0,024
Innovation output 1994–1996						
Product innovation	0,020	***	0,008	0,020	***	0,007
Process innovation only	0,017		0,015	0,018		0,015
R&D collaboration 1994–1996						
Domestic competitors	0,010		0,015			
Domestic consultants	-0,001		0,012			
Foreign competitors	0,020		0,015			
Foreign consultants	0,007		0,017			
R&D collaboration with competitors						
Domestic competitors				0,012		0,014
European competitors				0,004		0,016
American competitors				0,031		0,029
Japanese competitors				0,022		0,050
R&D diversity	-0,004		0,012	-0,006		0,012
Share of highly educated employees 1996						
Technical education	-0,042		0,086	-0,033		0,085
Commercial or social education	-0,010		0,028	-0,010		0,028
Other education	-0,017		0,026	-0,015		0,026
Spin-off of a large company	0,063	**	0,029	0,063	**	0,029
Sector						
High technology	-0,010		0,027	-0,009		0,027
High or medium high technology	0,010		0,019	0,011		0,019
Low or medium low technology	0,034	*	0,018	0,034	*	0,018
Low technology	0,001		0,016	0,001		0,016
Knowledge intensive services	0,031		0,021	0,031		0,021
Other services	0,038	**	0,019	0,037	**	0,019
Intercept	0,076		0,074	0,068		0,074
Mills	-0,054		0,038	-0,050		0,038
Number of observations	1672			1672		
Log likelihood	1241,283			1241,091		

Table A8. Heckman selection models for the post-innovation sales growth in the full sample of CIS3.

CIS3	**All without outliers**			
Dependent variable	**Model 1**		**Model 2**	
Average annual sales growth 2000–2004, log	**Coef. Sig.**	**Std. Err.**	**Coef. Sig.**	**Std. Err.**
Average annual sales growth 1996–2000, log	0,146 ***	0,017	0,145 ***	0,017
Average annual productivity growth 1996–2000, log	-0,041	0,028	-0,039	0,028
Number of employees 2000, log	0,008	0,005	0,007	0,005
Export share in sales 2000	-0,020	0,012	-0,020 *	0,012
Innovation output 1998–2000				
Product innovation	0,022 ***	0,007	0,017 **	0,007
Process innovation only	0,008	0,013	0,003	0,013
R&D collaboration 1998–2000				
Domestic competitors	-0,009	0,013		
Domestic consultants	-0,031 ***	0,010		
Foreign competitors	0,014	0,016		
Foreign consultants	-0,014	0,017		
R&D collaboration with competitors				
Domestic competitors			-0,021 *	0,012
European competitors			0,014	0,019
American competitors			-0,004	0,060
Japanese competitors			-0,033	0,030
R&D diversity	-0,003	0,012	0,002	0,012
Share of highly educated employees 2000				
Technical education	0,079	0,090	0,084	0,090
Commercial or social education	0,052 *	0,031	0,054 *	0,031
Other education	0,038	0,026	0,039	0,026
Spin-off of a large company	0,020	0,024	0,024	0,024
Sector				
High technology	0,003	0,030	0,013	0,030
High or medium high technology	0,016	0,021	0,022	0,021
Low or medium low technology	-0,002	0,019	0,003	0,019
Low technology	-0,022	0,017	-0,018	0,017
Knowledge intensive services	-0,014	0,017	-0,009	0,017
Other services	-0,017	0,016	-0,014	0,016
Intercept	-0,029	0,056	-0,039	0,056
Mills	0,010	0,032	0,018	0,032
Number of observations	1433		1433	
Log likelihood	1083,047		1078,499	

Table A9. Heckman selection models for the post-innovation productivity growth in the full sample of CIS2.

CIS2	**All without outliers**					
Dependent variable	**Model 1**			**Model 2**		
Average annual productivity growth 1998–2003, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1994–1998, log	-0,069	***	0,016	-0,068	***	0,016
Average annual productivity growth 1994–1998, log	0,083	***	0,022	0,083	***	0,022
Number of employees 1996, log	0,013	**	0,006	0,013	**	0,006
Export share in sales 1996	0,009		0,022	0,010		0,022
Innovation output 1994–1996						
Product innovation	0,002		0,007	0,003		0,007
Process innovation only	0,002		0,014	0,003		0,013
R&D collaboration 1994–1996						
Domestic competitors	-0,009		0,013			
Domestic consultants	0,011		0,010			
Foreign competitors	-0,008		0,014			
Foreign consultants	0,003		0,015			
R&D collaboration with competitors						
Domestic competitors				-0,005		0,013
European competitors				-0,012		0,014
American competitors				-0,008		0,026
Japanese competitors				0,037		0,045
R&D diversity	-0,023	**	0,011	-0,024	**	0,011
Share of highly educated employees 1996						
Technical education	0,092		0,076	0,094		0,076
Commercial or social education	0,036		0,025	0,037		0,025
Other education	0,016		0,023	0,017		0,023
Spin-off of a large company	0,040		0,026	0,044	*	0,026
Sector						
High technology	0,039		0,024	0,040	*	0,024
High or medium high technology	0,032	*	0,018	0,032	*	0,018
Low or medium low technology	0,019		0,016	0,019		0,016
Low technology	0,011		0,015	0,011		0,015
Knowledge intensive services	0,007		0,018	0,008		0,018
Other services	-0,014		0,017	-0,014		0,017
Intercept	-0,093		0,066	-0,095		0,066
Mills	0,058	*	0,034	0,059	*	0,034
Number of observations	1667			1667		
Log likelihood	1425,303			1425,221		

Table A10. Heckman selection models for the post-innovation productivity growth in the full sample of CIS3.

CIS3	All without outliers					
Dependent variable	**Model 1**			**Model 2**		
Average annual productivity growth 2000–2004, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1996–2000, log	-0,013		0,015	-0,013		0,015
Average annual productivity growth 1996–2000, log	0,093	***	0,024	0,094	***	0,024
Number of employees 2000, log	-0,001		0,004	-0,001		0,004
Export share in sales 2000	-0,019	*	0,011	-0,019	*	0,011
Innovation output 1998–2000						
Product innovation	0,016	**	0,006	0,013	**	0,006
Process innovation only	0,029	**	0,012	0,026	**	0,012
R&D collaboration 1998–2000						
Domestic competitors	0,008		0,011			
Domestic consultants	-0,018	**	0,009			
Foreign competitors	-0,015		0,014			
Foreign consultants	-0,007		0,014			
R&D collaboration with competitors						
Domestic competitors				0,001		0,011
European competitors				-0,031	*	0,017
American competitors				0,029		0,053
Japanese competitors				0,006		0,026
R&D diversity	-0,001		0,011	0,002		0,011
Share of highly educated employees 2000						
Technical education	-0,283	***	0,078	-0,284	***	0,079
Commercial or social education	-0,008		0,027	-0,006		0,027
Other education	-0,041	*	0,023	-0,040	*	0,023
Spin-off of a large company	0,007		0,021	0,008		0,021
Sector						
High technology	-0,026		0,026	-0,021		0,026
High or medium high technology	-0,026		0,018	-0,023		0,018
Low or medium low technology	-0,032	**	0,016	-0,030	*	0,016
Low technology	-0,038	***	0,015	-0,037	**	0,015
Knowledge intensive services	-0,010		0,015	-0,008		0,015
Other services	-0,016		0,014	-0,015		0,014
Intercept	0,104	**	0,049	0,099	**	0,049
Mills	-0,031		0,028	-0,027		0,028
Number of observations	1432			1432		
Log likelihood	1275,632			1274,271		

Table A11. Heckman selection models for the post-innovation sales growth among SMEs in CIS2.

CIS2	**SMEs with outliers**			**SMEs without outliers**		
Dependent variable	**Model 1**			**Model 2**		
Average annual sales growth 1998–2003, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1994–1998, log	0,143	***	0,032	0,061	***	0,019
Average annual productivity growth 1994–1998, log	-0,064		0,041	0,018		0,024
Number of employees 1996, log	-0,007		0,012	-0,005		0,007
Export share in sales 1996	-0,086		0,056	-0,045		0,036
Innovation output 1994–1996						
Product innovation	0,038	***	0,015	0,022	***	0,008
Process innovation only	0,038		0,029	0,015		0,017
R&D collaboration 1994–1996						
Domestic competitors	0,024		0,032	0,016		0,018
Domestic consultants	-0,041	*	0,024	-0,007		0,014
Foreign competitors	0,038		0,037	0,019		0,021
Foreign consultants	0,043		0,038	0,018		0,022
R&D collaboration with competitors						
Domestic competitors						
European competitors						
American competitors						
Japanese competitors						
R&D diversity	-0,031		0,027	-0,017		0,015
Share of highly educated employees 1996						
Technical education	-0,175		0,189	-0,037		0,114
Commercial or social education	0,006		0,060	-0,016		0,039
Other education	0,016		0,053	-0,003		0,031
Spin-off of a large company	0,098	*	0,057	0,066	**	0,032
Sector						
High technology	-0,023		0,059	0,010		0,035
High or medium high technology	-0,031		0,040	0,017		0,025
Low or medium low technology	0,011		0,034	0,038		0,020
Low technology	-0,034		0,031	-0,001		0,018
Knowledge intensive services	-0,052		0,043	0,026		0,025
Other services	-0,027		0,035	0,036	*	0,021
Intercept	0,081		0,169	0,042		0,104
Mills	-0,055		0,088	-0,039		0,056
Number of observations	1522			1464		
Log likelihood	231,106			1062,860		

Table A12. Heckman selection models for the post-innovation sales growth among SMEs in CIS3.

CIS3	**SMEs with outliers**			**SMEs without outliers**		
Dependent variable	**Model 1**			**Model 2**		
Average annual sales growth 2000–2004, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1996–2000, log	0,369	***	0,070	0,176	***	0,035
Average annual productivity growth 1996–2000, log	-0,090		0,120	-0,050		0,062
Number of employees 2000, log	-0,015		0,023	0,007		0,012
Export share in sales 2000	-0,024		0,050	-0,016		0,024
Innovation output 1998–2000						
Product innovation	0,119	**	0,050	0,035		0,024
Process innovation only	0,071		0,063	0,048		0,030
R&D collaboration 1998–2000						
Domestic competitors	0,023		0,019	-0,008		0,009
Domestic customers	-0,064	**	0,032	-0,009		0,015
Domestic consultants	-0,039	**	0,016	-0,017	**	0,008
Domestic suppliers	-0,021		0,014	0,004		0,007
Domestic universities	-0,006		0,014	0,002		0,007
Domestic research institutes	-0,018		0,030	0,023		0,014
R&D diversity	-0,031		0,038	0,012		0,018
Share of highly educated employees 2000						
Technical education	0,159		0,295	-0,084		0,143
Commercial or social education	0,063		0,127	0,111		0,068
Other education	-0,031		0,108	-0,013		0,055
Spin-off of a large company	0,014		0,087	-0,017		0,041
Sector						
High technology	0,131		0,126	0,136	**	0,063
High or medium high technology	0,076		0,094	0,094	**	0,047
Low or medium low technology	0,092		0,091	0,079	*	0,045
Low technology	0,042		0,089	0,047		0,044
Knowledge intensive services	0,036		0,089	0,088	**	0,044
Other services	0,019		0,091	0,051		0,045
Intercept	0,013		0,215	-0,095		0,110
Mills	-0,051		0,079	-0,017		0,040
Number of observations	362			348		
Log likelihood	2,982			266,156		

Table A13. Heckman selection models for the post-innovation productivity growth among SMEs in CIS2.

CIS2	**SMEs with outliers**			**SMEs without outliers**		
Dependent variable	**Model 1**			**Model 2**		
Average annual productivity growth 1998–2003, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1994–1998, log	-0,049	**	0,024	-0,070	***	0,018
Average annual productivity growth 1994–1998, log	0,053		0,033	0,082	***	0,024
Number of employees 1996, log	0,018	**	0,009	0,007		0,007
Export share in sales 1996	0,004		0,039	0,000		0,032
Innovation output 1994–1996						
Product innovation	0,012		0,010	0,001		0,007
Process innovation only	0,011		0,021	0,001		0,015
R&D collaboration 1994–1996						
Domestic competitors	-0,032		0,023	-0,022		0,016
Domestic consultants	0,003		0,017	0,016		0,012
Foreign competitors	-0,004		0,026	-0,011		0,019
Foreign consultants	0,017		0,027	0,016		0,019
R&D collaboration with competitors						
Domestic competitors						
European competitors						
American competitors						
Japanese competitors						
R&D diversity	-0,026		0,019	-0,025	*	0,014
Share of highly educated employees 1996						
Technical education	0,113		0,133	0,044		0,102
Commercial or social education	0,085	**	0,043	0,020		0,036
Other education	0,028		0,037	-0,003		0,028
Spin-off of a large company	0,055		0,040	0,047		0,029
Sector						
High technology	0,041		0,041	0,024		0,031
High or medium high technology	0,041		0,029	0,036		0,022
Low or medium low technology	0,020		0,024	0,020		0,018
Low technology	0,003		0,022	0,020		0,017
Knowledge intensive services	0,020		0,030	0,016		0,023
Other services	-0,034		0,025	0,006		0,019
Intercept	-0,164		0,119	-0,047		0,094
Mills	0,093		0,062	0,033		0,050
Number of observations	1514			1459		
Log likelihood	765,358			1217,884		

Table A14. Heckman selection models for the post-innovation productivity growth among SMEs in CIS3.

CIS3	**SMEs with outliers**		**SMEs without outliers**	
Dependent variable	**Model 1**		**Model 2**	
Average annual productivity growth 2000–2004, log	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Average annual sales growth 1996–2000, log	0,055	0,047	0,006	0,024
Average annual productivity growth 1996–2000, log	0,023	0,081	-0,081 *	0,043
Number of employees 2000, log	0,002	0,016	0,002	0,008
Export share in sales 2000	-0,015	0,034	-0,004	0,017
Innovation output 1998–2000				
Product innovation	0,107 ***	0,034	0,026	0,017
Process innovation only	0,096 **	0,042	0,040 *	0,021
R&D collaboration 1998–2000				
Domestic competitors	0,005	0,013	-0,003	0,006
Domestic customers	-0,046 **	0,021	-0,002	0,011
Domestic consultants	-0,019 *	0,011	-0,013 **	0,005
Domestic suppliers	-0,007	0,009	0,001	0,005
Domestic universities	0,003	0,010	0,006	0,005
Domestic research institutes	-0,035 *	0,020	-0,009	0,010
R&D diversity	-0,013	0,026	0,004	0,013
Share of highly educated employees 2000				
Technical education	-0,187	0,199	-0,321 ***	0,099
Commercial or social education	0,110	0,085	0,011	0,047
Other education	0,017	0,073	-0,044	0,038
Spin-off of a large company	-0,013	0,059	-0,023	0,029
Sector				
High technology	-0,005	0,085	0,022	0,044
High or medium high technology	-0,015	0,063	0,023	0,033
Low or medium low technology	-0,020	0,061	0,018	0,032
Low technology	-0,060	0,060	0,022	0,031
Knowledge intensive services	-0,045	0,060	0,033	0,030
Other services	-0,103 *	0,061	0,008	0,031
Intercept	0,013	0,144	0,050	0,077
Mills	-0,001	0,053	-0,039	0,028
Number of observations	362		348	
Log likelihood	146,421		392,436	

Table A15. Heckman selection models for the post-innovation sales growth among innovative firms in CIS2.

CIS2	Innovative firms with outlier			Innovative firms without outliers		
Dependent variable	Model 1			Model 2		
Average annual sales growth 1998–2003, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1994–1998, log	0,067		0,044	0,048	**	0,023
Average annual productivity growth 1994–1998, log						
Number of employees 1996, log	0,011		0,028	-0,011		0,008
Export share in sales 1996	0,011		0,150	-0,065	*	0,037
Innovation output 1994–1996						
Product innovation	0,070	***	0,022	0,026	**	0,012
Process innovation only	0,077	**	0,032	0,037	**	0,018
R&D collaboration 1994–1996						
Domestic competitors	0,030		0,030	0,014		0,014
Domestic consultants	-0,035		0,022	-0,001		0,011
Foreign competitors	0,052		0,034	0,023		0,015
Foreign consultants	0,039		0,035	0,003		0,017
R&D collaboration with competitors						
Domestic competitors						
European competitors						
American competitors						
Japanese competitors						
R&D diversity						
Share of highly educated employees 1996						
Technical education	-0,061		0,222	-0,007		0,105
Commercial or social education	0,129		0,105	0,047		0,046
Other education	0,045		0,092	-0,022		0,035
Spin-off of a large company	0,119	**	0,057	0,093	***	0,032
Sector						
High technology	0,074		0,106	-0,015		0,030
High or medium high technology	0,078		0,066	0,028		0,018
Low or medium low technology	0,090	***	0,033	0,051	***	0,015
Low technology	0,044		0,117	0,045	**	0,022
Knowledge intensive services	0,009		0,056	0,091	***	0,025
Other services						
Intercept	-0,265		0,459	0,084		0,104
millsrat	0,083		0,265	-0,079		0,060
Number of observations	540			534		
Log likelihood	138,055			533,410		

Table A16. Heckman selection models for the post-innovation sales growth among innovative firms in CIS3.

CIS3	**Innovative firms with outlier**			**Innovative firms without outliers**		
Dependent variable	**Model 1**			**Model 2**		
Average annual sales growth 2000–2004, log	**Coef.**	**Sig.**	**Std. Err.**	**Coef.**	**Sig.**	**Std. Err.**
Average annual sales growth 1996–2000, log	0,119	***	0,020	0,119	***	0,022
Average annual productivity growth 1996–2000, log				-0,003		0,039
Number of employees 2000, log	0,009		0,007	0,009		0,006
Export share in sales 2000	-0,020		0,016	-0,023		0,015
Innovation output 1998–2000						
Product innovation	0,018		0,013	0,018		0,013
Process innovation only	0,008		0,018	0,009		0,018
R&D collaboration 1998–2000						
Domestic competitors	-0,009		0,013	-0,009		0,013
Domestic consultants	-0,031	***	0,010	-0,031	***	0,010
Foreign competitors	0,014		0,016	0,014		0,016
Foreign consultants	-0,014		0,017	-0,014		0,017
R&D collaboration with competitors						
Domestic competitors						
European competitors						
American competitors						
Japanese competitors						
R&D diversity				-0,004		0,012
Share of highly educated employees 2000						
Technical education	0,061		0,112	0,053		0,104
Commercial or social education	0,067		0,044	0,064		0,041
Other education	0,058		0,036	0,057	*	0,033
Spin-off of a large company	-0,003		0,027	-0,004		0,027
Sector						
High technology	0,015		0,030	0,025		0,036
High or medium high technology	0,043	**	0,017	0,054	**	0,027
Low or medium low technology	0,026	*	0,014	0,038		0,025
Low technology				0,015		0,024
Knowledge intensive services	0,003		0,017	0,015		0,024
Other services	0,002		0,019	0,015		0,025
Intercept	-0,063		0,074	-0,066		0,066
millsrat	0,018		0,050	0,011		0,038
Number of observations	811			809		
Log likelihood	624,026			621,765		

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Abstract
The aim of this study is to analyse the dynamic effects of innovation and collaboration in innovation on the growth performance of Finnish firms. We are mainly interested in the long run (5 years) average annual growth rates of innovative firms. We first review the literature on growth theories of firms and on the empirical research on innovation and firm growth. Then we conduct partial panel data analyses of the determinants of growth in sales, employment and productivity for firms included in the Finnish Community Innovation Surveys (CIS). Besides collaboration in innovation, we also utilize existing data on the corporate spin-offs of large manufacturing firms. We use two waves of the CIS, CIS2 and CIS3, and link them separately with growth performance data taken from the Business Register, with patent data taken from the Patent Register and with education data taken from the Employee-Employer Dataset.

We use the Heckman two-step selection model together with a single-equation OLS and ML estimation method for the long run growth rates of firms, and a variant of the Crépon, Duguet, Mairesse (CDM) structural model for the productivity levels of firms. We obtain only partial evidence that process and product innovations affect significantly and positively the post-innovation total sales growth among innovation active firms. Similarly, we find only partial evidence that collaboration in innovation with foreign competitors and being established as spin-offs of large firms affects the total sales growth. Nonetheless, the relationship between the occurrence of innovations and the future productivity growth of innovative firms comes out as a robust result.

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The determinants of the average growth of innovative firms and corporate spin-offs are investigated in this report in order to establish how growth performance is influenced by the governance of corporate innovation activities. In particular the focus is on the role of collaboration for innovation when the long run is considered. Besides an extensive and well elaborated theoretical discussion and literature review of the current academic discourse of the issue the author utilizes data for his empirical analysis which hitherto has not been utilized to this extent. The data set which is the basis for his profound empirical analysis is not only rather extensive in size and coverage; it is also of highest statistical quality as the author accesses data generated and compiled by Statistics Finland. The estimation results offer new insight into the whole domain of innovation collaboration and the determinants of corporate growth.

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