ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS
The Research Institute of the Finnish Economy
Lönnrotinkatu 4 B 00120 Helsinki Finland

Sarja B 168 Series

Rita Asplund (Ed.)

PUBLIC R&D FUNDING, TECHNOLOGICAL COMPETITIVENESS, PRODUCTIVITY, AND JOB CREATION

ETLA, The Research Institute of the Finnish Economy

Publisher: Taloustieto Oy

Helsinki 2000

Cover: Mainos MayDay, Vantaa 2000

ISBN 951-628-325-X
ISSN 0356-7443

Printed in: Tummavuoren Kirjapaino Oy,
Vantaa 2000

ASPLUND, Rita (Ed.), **PUBLIC R&D FUNDING, TECHNOLOGICAL COMPETITIVENESS, PRODUCTIVITY, AND JOB CREATION**. Helsinki. ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2000, 171 p. (B, 0356-7443; No. 168). ISBN 951-628-325-X.

ABSTRACT: This book explores the impact of public R&D funding on the economic performance of Finnish firms, especially in terms of productivity growth and job creation. Special attention is thereby paid to the potential influence exerted by two crucial characteristics of firms – their size and their sector of activity. The emphasis is on unravelling the economic effects of the public support handled by the National Technology Agency (Tekes), which is the main channel for distributing government R&D loans and direct subsidies to the business enterprise sector.

The analyses reported here use both descriptive and econometric tools, and produce a multitude of results with respect to R&D efforts as well as other determinants of firms' productivity and employment capacity. In brief the results point to only weak, if any, direct productivity- and employment-enhancing effects of public R&D support. The influence mediated through the innovative creativity of the firms' industrial environment, in contrast, turns out to be of crucial importance, indicating that public R&D policies and government interventions evidently have an indirect effect at least.

KEY WORDS: employment, firms, job creation, manufacturing, productivity, public support, R&D, services, size

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TIIVISTELMÄ: Tässä kirjassa tutkitaan julkisen T&K-rahoituksen merkitystä suomalaisille yrityksille erityisesti tuottavuuden kasvun ja työpaikkojen luomiskyvyn näkökulmasta. Tähän liittyen kiinnitetään erityistä huomiota yritysten kahden tärkeän ominaisuuden, koon ja toimintasektorin, mahdollisiin vaikutuksiin. Tavoitteena on selvittää Teknologian kehittämiskeskuksen (Tekesin) käsittelemän julkisen tuen talousvaikutukset. Tekes on yrityssektorille suunnattujen valtion T&K-lainojen ja suorien tukien pääjakelukanava.

Kirjassa selostetut tutkimukset käyttävät hyväkseen sekä deskriptiivisiä että ekonometrisiä apukeinoja ja sisältävät suuren joukon T&K-panostuksiin ja muihin yritysten tuottavuuteen ja työllisyyskehitykseen vaikuttaviin tekijöihin liittyviä tutkimustuloksia. Tulosten mukaan julkisella T&K-tuella ei ole kuin enintään heikkoja suoria tuottavuutta ja työllisyyttä kohentavia vaikutuksia. Sen sijaan yritysten teollisen ympäristön innovatiivisen luovuuden välittämä vaikutus osoittautuu ratkaisevan tärkeäksi tekijäksi. Julkisilla T&K-ohjelmilla ja valtion väliintulolla on siten selvästi ainakin välillisiä vaikutuksia.

AVAINSANAT: julkinen tuki, koko, palvelut, T&K, tehdasteollisuus, tuottavuus, työllisyys, työpaikkojen luominen, yritykset

Preface

This book is a report of studies evaluating the impact of public R&D funding on the productivity and employment performance of Finnish firms, with special attention paid to the potential role in this context of the firm's size and sector of activity. The emphasis is on exploring the economic effects of the public support allocated by the National Technology Agency (Tekes) in the 1990s.

The study has been undertaken as part of a large evaluation project titled *Innovation policies and public R&D – Impacts on firm performance and job creation.* It was initiated by the committee appointed by the Ministry of Education and by the Ministry of Trade and Industry. We wish to thank the committee for its continuous encouragement and many constructive comments on earlier versions of this report. Members of the committee have been Dr. Aatto Prihti, president of Sitra, the Finnish National Fund for Research and Development (chair), professor Luke Georghiou, PREST, University of Manchester, Dr. Elisabeth Helander, European Commission, Dr. Jyrki Juusela, Outokumpu Oyj, professor Frieder Meyer-Krahmer, Fraunhofer Institute for Systems and Innovation Research, professor Bertil Roslin, Åbo Akademi, Dr. Tuire Santamäki-Vuori, The Municipal Workers' and Employees' Union KTV and Ms. Mirja Gröhn, Sitra (secretary). Acknowledgements are also due to Statistics Finland and Tekes for making the data sources available to us that were crucial for constructing the unique firm/plant-level data set used in the study.

The main chapters of this volume have been written by Olavi Lehtoranta and Mika Maliranta, with complementary chapters produced by Antton Lounasheimo and Synnöve Vuori. The research work has been co-ordinated by Rita Asplund and Pekka Ylä-Anttila. Anthony de Carvalho has kindly corrected the text into proper English and Tuula Ratapalo has professionally given it its final layout. Parts of the text have been translated into Finnish by Antton Lounasheimo. Kimmo Aaltonen has provided the final touches to the figures.

Helsinki, September 2000.

Pentti Vartia

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Chapter 1

INTRODUCTORY SUMMARY

Rita Asplund

Investment in intangibles is a crucial pillar in today's knowledge-based economies. Firms make considerable efforts to base their competitiveness on human resources and increasingly also on technological innovations. Successful innovations, however, depend not only on the quantity and quality of a firm's intangible assets. Equally important are efficient use of its cumulated skills and creativity, and continuous access to new knowledge through spillovers and co-operation with other firms and research bodies.

Finland, together with the other Nordic countries and France, rank highest in a recent OECD comparison of investment in knowledge, defined as the sum of expenditure on R&D, public spending on education, and investment in software (OECD, 1999). This position has been reached due to the highest average annual growth rate (3.9%) in this type of investment in the OECD area over the period 1985 to 1995. Simultaneously the rapid growth in resources spent on production of knowledge has made investments in knowledge even more important than investments in machinery and equipment.[1] Apart from their own intangible assets, Finnish firms in trying to respond to the globalisation challenge have benefited much both from spillovers and to an increasing extent also from co-operation arrangements.[2] Indeed, the International Institute for Management Development (IMD) has in the past few years ranked Finland as the world leader in technological co-operation between firms and also in research co-operation between firms and universities.

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1 According to figures for Finland for 1995, investments in knowledge made up 9.5% of GDP compared to 7.0% for machinery and equipment and 9.2% for other physical investment (OECD, 1999, Annex Table 2.1.1). The major component in investments in knowledge is public spending on education (6.2% of GDP) compared to a GDP share of 2.1% for R&D and 1.2% for software.

2 There is a huge body of empirical evidence verifying the positive effect of spillovers in the technological progress of Finnish industries and firms, see e.g. Vuori (1994, 1995, 1997a, 1997b). A recent in-dept analysis of Finnish manufacturing further suggests that these spillovers arise primarily from intra-industry rather than inter-industry externalities, and that the social rate of return on R&D is roughly 10% above the private return on R&D (Rouvinen, 1999). Recent evidence also highlights the extent and importance of co-operation agreements for innovative activities of Finnish manufacturing and service sector firms (Leiponen, 2000a; 2000b). Also see OECD (1999, Figure 4.5 and Annex Table 4.5.1).

1 R&D efforts of Finnish business enterprises[3]

The steady increase in R&D investment in the 1980s speeded up during the 1990s. In the early 1980s Finland allocated about 1% of GDP to R&D investment, as measured by gross domestic expenditure on R&D. At the turn of the decade, this share had reached the 2% level and had, by the end of the millennium, broken the 3% level. These R&D efforts have placed Finland among the top-ranking countries of Japan, South Korea, Sweden and the USA.

The extraordinary increase in R&D expenditure towards the end of the decade was the outcome of a joint commitment of the private sector and the government in 1996 to increase R&D expenditure to 2.9% of GDP by 1999. This goal was, in effect, exceeded already in 1998. A substantial portion of the increase in public R&D funding came from the sell-off of state-owned firms. These funds were to most part allocated to technology, targeted basic research, and education. In relation to this re-orientation in Finnish technology policies also a new Subsidies Act concerning the general conditions for the provision of industrial subsidies was passed in 1997. With this new provision the whole support system was put under continuous evaluation as well.[4] The goal for 2004 has been set at 3.5% of GDP.

As in most other OECD countries, an increasing share of R&D activities is performed by the business enterprise sector. In 1997 close to 70% of R&D was executed by business enterprises, compared to some 55% in the early 1980s and some 62% in 1990. In line with this, business R&D intensity (in domestic product of industry) has shown one of the highest annual growth rates (7.3%) in the OECD area since the early 1990s. In 1997 business R&D intensity amounted to 2.7%, with only Sweden showing a higher figure (4.4%). The growth in business R&D intensity can be traced to increased R&D activities in virtually all industries in both manufacturing and services.

The business enterprise sector not only performs but also funds an increasing share of R&D activities. Since the early 1980s its funding share has expanded from some 55% to nearly 63% (in 1997). As a percentage of GDP this corresponds to an increase from 0.65% up to

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[3] This section is based mainly on data published in OECD (1999), EC-DGXII and Eurostat (1999) and in the series R&D statistics of Statistics Finland.

[4] For more details, see e.g. Kauppinen (1998).

1.75%, again a top-ranking figure among OECD countries. Simultaneously the relative importance of government funding of R&D has declined. This is due not to an absolute decrease in government sources devoted to R&D but to a growth rate in public R&D funding that has failed to keep pace with that in private R&D funding.[5] As a percentage of GDP the share of government funding of R&D remained at the 0.8–0.9% level through most of the 1990s (compared to less than 0.7% in the 1980s), and rose to around 1% due to the notable increase in government R&D funding that occurred in 1998 and 1999. As a percentage of business R&D expenditure the share of government funding is, nevertheless, still one of the lowest in the OECD area (less than half of the OECD average).

In addition to R&D support, government provides funding for industrial technology also in other modes. OECD calculates that total government support to industrial technology relative to domestic product of industry has in Finland amounted to over 0.6% for most of the 1990s. This is, in effect, the highest figure among the ten OECD countries for which such data are available. And in contrast to most other countries, the overall trend is increasing rather than decreasing. Simultaneously the relative importance of the main components of government support has shifted to a steadily growing role of financial incentives, mainly grants and subsidies (from some 30% in the early 1990s to 45% in 1997) and mainly in support of business R&D. These profound structural changes mirror the re-orientation in Finnish technology policy in the 1990s.

All in all, in the 1990s Finland performed extremely well when it comes to private as well as public R&D funding both in a historical perspective and in OECD-wide comparisons. As often pointed out, however, the relation between input and output is not necessarily linear in innovative activities. Accordingly it is highly relevant to ask what the outcome of this enormous investment in business R&D has been in terms of innovative output and economic performance. This is also the question addressed in the present study.

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[5] See R&D statistics published by Statistics Finland. Also see e.g. OECD (1998, 2000).

2 Main purpose of the study

The main purpose of the present study is to try to explore, using both descriptive analysis and econometric modelling, the interrelation between R&D expenditure and the economic performance of firms. Of particular interest is the role played by government-funded business R&D.

In other words, the focus is on evaluating the economic benefits of business sector R&D investment and especially of that financed out of public funds. The study is not concerned with the question whether or not the government should support business enterprise sector R&D activities. Nor does it address the question of the efficiency of the current modes of government support. Today's Europe seems to have reached broad consensus concerning the first question in that government support for R&D activities usually renders favourable treatment in the rules concerning state aid that the European Union has adopted.[6] Moreover, the technology policy strategy of Finland explicitly identifies the need of the government to intervene in order to reduce market failures that arise from insufficient investment in research, development and education.[7] The second question is definitely more challenging, both theoretically and empirically. Obviously this is also the main reason why it has so far received only limited attention.[8]

The evaluation analyses reported in this volume have, for various reasons, been restricted in certain respects. First, the analyses only cover public funding directed towards R&D investment and, furthermore, primarily the R&D funding handled by the National Technology Agency (Tekes). Tekes has a budget from the state and is the main financing organisation for applied and industrial R&D. Indeed, over the past decade, Tekes has provided between 75 and 80% of the public R&D funding received by manufacturing firms. Annual reports of Tekes also tell us that its share in the total costs of the product development projects it has funded since the mid-1990s, has amounted to some 40%, on average.

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[6] For details, see e.g. Walther and Joels (1998). For a more general discussion of the justification of public action to support business innovations, see e.g. Pretschker (1998).

[7] See further e.g. Kauppinen (1998).

[8] Martin and Scott (2000), for instance, emphasise that since the forces that cause innovation market failure differ from sector to sector, this needs to be accounted for in the design of public support for private innovation.

Second, the analyses are based on a unique firm/plant-level database of Statistics Finland that has been compiled by merging administrative registers concerning firms, plants and their workers. To this database also information from the funding registers of Tekes has been added. The database is outlined in a separate appendix of Chapter 3 while additional details are provided in the text of the different chapters. Due to lags in data production, however, the analyses can, at best, be extended to the year 1998. This means that the analyses cover only partly the strong increase in public R&D funding that has occurred over the past few years. On the other hand, investment in R&D, regardless of the origin of funding, usually affects output with a notable lag. The joint R&D efforts of the private and the public sector in recent years can therefore be properly evaluated after a few years, at the earliest.

Third, the economic outcome of R&D expenditure is evaluated in merely two, but highly relevant dimensions: in relation to firms' productivity, on the one hand, and their job creation capacity, on the other. Here the objective is to capture and quantify potential direct links between firms' R&D expenditure and their productivity and employment performance. Possible indirect effects are mostly left to speculation. A limited number of indicators measuring the output of firms' innovative activities is also utilised in the analyses. Partly these indicators are of interest in themselves; partly they provide the possibility to add additional aspects of firms' R&D activities to the analyses. Among the measures of innovative output showing up in the subsequent analyses are patents and indicators of whether or not the firm has introduced new or improved products and/or processes on the market over the analysed period of time.[9]

Finally, apart from a business-wide approach, attempts are also made to explore differences between firms in their R&D expenditure and public R&D funding and possible implications of these differences for their economic performance. The focus is on two essential characteristics of firms: their sector of activity – manufacturing versus service sector firms, and their size – large contra small firms. Both dimensions are of high priority in Finnish technology policies of today[10], and both categories

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9 It may be noted that also the OECD measures firms' innovative output using these two types of indicators. See OECD (1999, Sections 11.2 and 11.4).

10 OECD comparisons show that in contrast to the average trend in the OECD area, in Finland government support to business R&D is skewed towards small firms (OECD, 1999). Indeed, in 1997 the share of government-financed business R&D in total business R&D was substantially higher in small firms than in large ones. It amounted to 8.2% for firms with less than 500 employees and to 11.7% for firms

have rapidly increased their share also in the R&D funding provided by Tekes. As will be noticed from the results reported in the subsequent chapters, however, only cautious conclusions can be drawn for firms of different size and sector. A major reason for this is that both small firms and service sector firms are still underrepresented in the available firm-level data. With the continuously improved coverage of these two categories of firms in R&D statistics also their share in R&D has shown a steady growth. This, of course, affects the obtained results.

3 Summary of the content and main findings of subsequent chapters

The rest of this introductory chapter summarises the main findings reported in Chapters 2 to 4. Chapter 2 contains a descriptive comparison of supported and non-supported business firms in terms of their economic performance in various dimensions. Chapters 3 and 4 extend the analysis to econometric modelling of the relationship between public R&D support and, respectively, productivity performance and job creation. The two appendix chapters are not commented on in detail. The first appendix chapter, written by *Synnöve Vuori*, presents a brief review of existing empirical evidence, mainly for Finland, within the field covered in this volume. The second appendix chapter, written by *Antton Lounasheimo*, highlights – from a more general point-of-view – the current knowledge in Finland on the relationship between technology and jobs.

3.1 Technology-based firms and public R&D support: A descriptive introduction (Chapter 2)

In Chapter 2, *Olavi Lehtoranta* provides a comprehensive illustration of the data on public R&D support made available by Tekes, the main channel for distributing government R&D loans and direct subsidies to the business enterprise sector. Simultaneously this chapter fills the role of making the reader familiar with the data underlying the evaluations,

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with less than 100 employees. This is to be compared with a share of 2.4% for firms with 500 or more employees and 1.5% for firms with 1000 and more employees. Of total business R&D, however, large firms (500 or more employees) fund a substantially higher share (71% in 1997).

reported in Chapters 3 and 4, of the effects of public R&D funding on the productivity and job creation performance of supported firms.

The examination of the number and distribution of supported firms covers a multitude of perspectives to the issue, including the relevance and justification of the way the data have been merged and restricted. In addition to merely looking at supported and non-supported firms, Lehtoranta also explores the frequency of R&D support in terms of approved and rejected projects, permanence profiles of firms (regular versus occasional applicants), and the number of years over which the R&D support was paid. A distinct trend over the investigated 1991–1998 period is an increasing dominance of smaller firms among the approved firms and also of service sector firms. This is in line with the re-focusing of Finnish technology policies in the 1990s that was briefly discussed earlier.

Comparison of supported and non-supported firms in a variety of dimensions reveals several interesting similarities and, particularly, dissimilarities between the two groups of firms. Cautious generalisation of the main findings suggests the following. The supported firms are, on average, characterised by higher productivity levels and also by higher productivity growth rates. Moreover, the link between R&D support and productivity growth seems to have strengthened over time especially among service sector firms. Among large firms, however, the non-supported firms have persistently showed higher productivity growth.

R&D intensity (R&D expenditure per turnover) proves to be considerably higher among supported firms. On the other hand, common features of supported and non-supported firms (in manufacturing as well as services) are R&D intensity levels that are increasing over time but decreasing with firm size. The size differences in relation to business-financed R&D are notably smaller, which lends further support to government-financed R&D being relatively more important for smaller firms (cf. footnote 11 above).

Also capital intensity levels (capital stock/employee) turn out to be markedly higher in supported firms, but persistently so only in manufacturing. The picture is less clear-cut when it comes to service sector firms. The overall impression, however, is that even when the category of supported firms falls below that of non-supported firms in average capital intensity, the difference is not large. Lehtoranta puts forth the hypothesis that the development of new information technologies has induced Tekes to switch the R&D support allocated to service sector firms from high capital intensity to high R&D intensity ones.

In view of the comparatively high R&D intensity of supported firms it is hardly surprising that patenting is much more common among R&D support receiving firms, as is also the degree of product and process innovativeness. The difference between supported and non-supported firms in patenting behaviour is conspicuous in the largest size group. Also the notably larger share of higher-educated employees with a degree in engineering or natural sciences in supported firms is only to be expected in view of their higher R&D intensity level. A well-educated research staff is evidently used by Tekes as a criterion when evaluating applications for R&D support.

3.2 Privately and publicly financed R&D as determinants of productivity – Evidence from Finnish enterprises (Chapter 3)

Attempts to unravel the role of public R&D support in boosting productivity growth have so far been reported in only a few studies for Finland. The analysis undertaken by *Mika Maliranta* in Chapter 3 differs from these previous studies with respect both to approach, method and data set used. Nevertheless the main findings concerning public R&D funding to business firms are basically the same as in previous studies: the analysis provides only weak, if any, support for public R&D support having a direct positive impact on the productivity performance of the supported firms. The same conclusion is drawn concerning privately financed R&D efforts. This outcome, however, seems to be at least in part explained by the turbulent and in several respects extraordinary economic period investigated, that is, the years 1988 to 1996.

These results do not change markedly depending on whether productivity is measured as labour productivity or as total factor productivity. Neither does the length of the period over which productivity growth is calculated affect the main outcome. Moreover, the negligible appearance of R&D-induced productivity growth is found to hold for the manufacturing sector as well as for the services sector and also across firms of different size.

In contrast to the firm's own R&D efforts, the R&D intensity characterising the firm's industrial environment is shown to exert a substantial influence on its productivity. This indicates that public R&D policies and government interventions evidently raise productivity through diffusion mechanisms that help firms adopt and exploit new technologies. These industry-specific spillovers are beneficial for both supported and non-supported firms and, indeed, turn out to be particularly important for small firms. Maliranta hypothesises that large firms are often engaged in several industries, for which reason the R&D spillovers in their main industry are not equally decisive as for smaller firms.

In addition to firm- and industry-specific R&D intensity Maliranta accounts for a broad set of other background factors that can be expected to affect productivity growth. As in previous studies, a high educational level of the firm's workforce is estimated to have a strong productivity-inducing effect. The impact of changes in the shares of the highly educated, on the other hand, is less clear-cut. A cautious interpretation of the results would suggest the following. An increase in the share of employees with a higher degree in engineering or natural sciences affects the productivity performance mainly of manufacturing firms and, moreover, only in the longer run. The productivity performance of service sector firms, in contrast, seems to be more linked to increases in the employee share of higher educated with a degree in some other field than engineering and natural sciences. These productivity effects also tend to arise within a much shorter time span than those induced by a technically trained workforce. One possible interpretation of this difference in outcomes is that service sector firms are more dependent on short-run productivity gains and therefore prefer to invest in other than technical skills. The activities of manufacturing firms, in turn, are dominated by product development and, therefore, are more strongly focused on favourable productivity performance in a longer-run perspective. The positive impact on productivity growth reported for product innovations can be taken to support this contention.

Maliranta also finds that foreign-owned firms tend to achieve faster productivity growth as compared to domestic-owned firms. This difference in productivity performance, however, does not seem to origin in different productivity-inducing effects of the firms' R&D efforts; Maliranta obtains no support for such a difference in R&D returns between foreign- and domestic-owned firms.

Maliranta concludes by discussing several potential ways in which the analysis of the interrelation between R&D efforts and productivity growth could be improved. Among the many options available, the creation of better-quality data is definitely a crucial one.

3.3 Job creation by supporting technology advances? – Evidence from Finnish plants (Chapter 4)

In Chapter 4, *Mika Maliranta* reports on a pioneering analysis of the evolution of the job creation capacity of Finnish plants over the turbulent economic period of 1986 to 1998. The emphasis is on comparing manufacturing plants differing in R&D intensity and size, and also on contrasting this evidence against the R&D intensity–job creation interrelation in the services sector. The role of government-financed R&D efforts for employment growth is one important dimension in the analysis.

Maliranta illustrates the magnitude of and trend in job and worker flows by using a broad set of illuminating flow measures, the calculation of which is made possible by access to a unique plant-level data set. These flow measures are carefully defined and discussed in the text. Several interesting patterns emerge from separate examination of (1) manufacturing plants differing in R&D intensity; (2) small manufacturing plants differing in R&D intensity; (3) Tekes-supported versus non-supported manufacturing plants; and (4) service sector plants differing in R&D intensity.

The flow rates calculated for the manufacturing sector indicate that high R&D intensity plants have been the most successful ones in terms of both job creation and net employment growth during the economic recovery that followed upon the deep recession in the early 1990s. However, this job creation capacity is found to have varied substantially across high R&D intensity plants. This heterogeneity in outcomes indicates, in turn, that a high R&D intensity level does not necessarily mean that the plant is also successful in creating new jobs. Indeed, the link between R&D efforts and employment growth proves to be much more straightforward, albeit weaker, among medium R&D intensity plants. Furthermore, the strong (net) job creation capacity of high R&D intensity plants turns out to have been coupled also with comparatively high worker turnover rates. Maliranta hypothesises that the jobs created especially in high R&D intensity plants have demanded new types of skills and that this has started a large-scale jobs-skills matching process in these plants.

The job and worker flows calculated for plants engaged in the services sector reveal a conspicuous similarity with those obtained for manufacturing plants. In other words, irrespective of sector high, medium and low R&D intensity plants seem to behave in much the same way when it comes to job creation and re-structuring of the labour force. This finding is in line with recent evidence for Finland pointing to a high degree of similarity between manufacturing and services also with respect to innovation activities (Leiponen, 2000a).

The patterns observed for the manufacturing sector as a whole are much less outstanding when restricting the comparison to small plants with less than 50 employees and, furthermore, to the post-recession period. The differences in the various flow measures between small plants differing in R&D intensity have to most part narrowed and occasionally even turned negligible in the post-recession years. Nevertheless the overall impression mediated by these job and worker flow rates is that small, low R&D intensity plants still contribute the least to job creation and also offer the most risky jobs. Similar results are reported in a recent study of unemployment risks among Finnish manufacturing workers based on individual-level data (Asplund, 2000).

When finally comparing the performance of manufacturing firms and plants having received support from Tekes with that of the non-supported ones, Maliranta notes that the supported units have, especially in more recent years, contributed much more to net employment growth than the non-supported ones. The supported units also seem to have been able to offer more stable positions as measured by the flow rate into unemployment. Compared to non-supported medium and high R&D intensity firms, however, they have on average recruited unemployed at a slightly lower rate.

The main findings from the econometric analysis are basically in line with the broad pictures drawn from the descriptive inspection. Both the firm's total R&D effort and the industry-specific R&D intensity level – the R&D environment of the firm – are found to have had a positive impact on net employment growth in manufacturing. The significantly positive impact on net job creation of the firm's R&D effort is retained also when restricting the variable to reflect only the privately financed part of the firm's R&D expenditures. The remaining – i.e. publicly financed – part of the firm's R&D expenditures, on the other hand, comes out with a large but insignificant estimate. In other words, the evidence on public R&D funding having a direct influence on the job creation capacity of the supported firms remains ambiguous.

As in the case of the productivity growth analysis in Chapter 3, there are without doubt important diffusion mechanisms at work also when it comes to job creation. Most clearly this is indicated by the positive effect of industry-specific R&D on net employment growth. When further taking into account that industry-specific R&D intensity was found also to improve the productivity performance of firms and that productivity growth affects job creation, the total R&D stock of an industry does seem to be a crucial policy tool. Moreover, these findings can be added to the steadily growing empirical literature verifying the importance of spillovers in business R&D activities and, accordingly, may be argued to provide a major justification for public R&D support to reduce innovation market failures and to promote economy-wide productivity and employment growth.

Next Maliranta extends his econometric exercise to the influence exerted by the size of the manufacturing firm. He founds that a creative environment is of particular importance for net employment growth in small and medium-sized firms, whereas the R&D efforts undertaken within the firm play a much more important role for the job creation capacity of large manufacturing firms. Interacting the variables capturing the publicly financed component of the firm's R&D with size dummies, however, adds nothing new to the results. More precisely, irrespective of the size of the manufacturing firm public R&D funding does not show up with a direct effect on net employment growth (except for the combination of large firms and non-Tekes support).

The econometric analysis of service sector firms largely repeats the results obtained for the manufacturing sector. The similarity in results extends also to the publicly financed part of the firm's R&D efforts.

Maliranta concludes by emphasising the strong empirical evidence of his analysis in support of the contention that high R&D firms play a crucial role in creating both new and stable jobs. In this sense, especially high R&D firms can be expected to reduce unemployment. Maliranta, however, pushes this discussion one step further by including yet another aspect, viz. the structure of today's labour demand and the obviously quite weak prospects of particularly low-skilled unemployed of finding a job in these job-creating high-tech, high-productivity firms. This aspect is relevant also in relation to public R&D funding as an increasing proportion of this support is allocated to actually and/or potentially high-performing firms with an increasing demand for high-skilled employees.

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Chapter 2

TECHNOLOGY-BASED FIRMS AND PUBLIC R&D SUPPORT: A DESCRIPTIVE INTRODUCTION

Olavi Lehtoranta

Acknowledgements: Data on the performance measures of R&D firms were provided by Merja Kiljunen and Mika Maliranta, who also constructed the data sets used in Section 3 of this chapter. A part of the text in this section was originally written by Synnöve Vuori. I thank Rita Asplund and Mika Maliranta for their many valuable comments when I worked with the themes of this research.

1 Introduction

This study first considers the number of technology firms in Finland in the 1990s. Technology firms are here defined as firms that have stated in R&D surveys that they conduct R&D activities or that have submitted applications for R&D support to Tekes, the National Technology Agency of Finland. The estimated numbers of R&D firms are taken from the R&D statistics published by Statistics Finland. Our main concern is to establish the number of R&D firms that have been publicly supported and find out whether noticeable changes have taken place in the distribution of R&D subsidies among these firms in the 1990s. Because of the limited availability of firm-level data on public subsidies we consider here only the R&D support channelled through Tekes. The data on R&D support are based on two Tekes Registers, one containing data on project approvals (*approval data*) and the other on paid subsidies (*payment data*). In this chapter, we use both these data sets.[1]

After considering the number of firms that had their application(s) for R&D support approved/rejected by Tekes in the 1991 to 1998 period (hereafter: *approved/rejected firms*) a look will also be taken at the key characteristics of the supported and non-supported firms. For this purpose we mainly use the combined firm-level data sets that are described in Appendix 1 of Chapter 3 of this volume and that are also used in the subsequent analyses of the impact of privately and publicly financed R&D on firm-level productivity and job creation. The sample frame on which the analysis is based is constructed around the different annual files of the R&D surveys. A combination of these files is linked with annual data sets of the Business Register and Financial Statements surveys, annual data on the *paid R&D support*, as well as with annual data from the Business Taxation Register. In addition, data on patent applications and patents granted in the USA, as well as those from Register-based Employment Statistics and the 1996 Community Innovation Survey (CIS 2) are used.[2]

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1 A more detailed description of the Tekes data sets used in this chapter is given in Lehtoranta (2000).

2 There are two exceptions in the use of the data sets in this research. First, when studying the number and distribution of approved and rejected R&D firms in Section 2 (Figures 2–5), we use the *approval data* in 1991 to 1998 from the Tekes Register linked only with the combined data of the annual statistical files of the Business Register in 1989 to 1998. Using this link allows us to exclude applicants that are not enterprises but associations, universities or research institutions. Second, when ex-

In this chapter we mainly use the Tekes payment data and define a firm as "supported" if it has received a piece of R&D subsidy during the year under consideration or during some other period of years. Otherwise, a firm is defined as "non-supported". It is worth noting here that the group of "non-supported" firms also includes many non-R&D firms, as well as firms that have not applied for R&D support from Tekes.

In Section 2 we define a firm as "supported" (approved) if at least one of the firm's project applications has been approved during the whole time period between 1991 and 1998 and, contrastingly, as "non-supported" (rejected) if the firm has submitted one or more applications to Tekes between 1991 and 1998 but has had all of them rejected. In Section 2 we also consider the firms that have been approved in a specific year. For comparison purposes, we utilise the *use data* on Tekes subsidies, taken from the 1998 R&D survey, in addition to the payment data.

The specific definition of supported and non-supported firms used in Section 2 allows us to make a fairly clear-cut distinction between the R&D firms that have received support from Tekes and those that have not. This definition derives from the finding that a firm's applications for support may be both approved and rejected during consecutive years and that the support decision is dependent on the project characteristics (characteristics of technologies to be developed) rather than on the accounted firm characteristics in the group of applicants (for more discussion on this, see Lehtoranta, 2000, p. 18 and 34).

In Section 3, where the key characteristics of the supported and non-supported firms are under consideration, we define a firm as "supported" if it has received a payment of R&D subsidy during the years *t*–2, *t*–1 or *t*.[3] The payments of R&D subsidies are typically distributed over several consecutive years and all these items should be taken into ac-

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amining the market introduction of innovations of the supported and non-supported firms in Section 3 (Table 10), we link the Tekes payment data *direct* with the sample of the 1996 Innovation Survey, without first linking the data on paid R&D support with the combined sample of annual R&D surveys, as we do when we consider the other key characteristics of the supported and non-supported firms in Section 3.

3 In Table 4 we allow a two to four years' time lag from the paid R&D support, i.e. we define a firm as "supported" if it has received a payment during the years *t*–4, *t*–3 or *t*–2. There were, however, no big observable differences even when we used time lags of differing lengths.

count if the impact of the amount of the R&D subsidies granted by Tekes is to be properly analysed.

To provide the maximum amount of descriptive information on the firms having and not having received R&D support from Tekes, each of the tables in Section 3 presents the performance measures with the firms also classified according to size and industrial sector. The size groups are small firms (less than 50 employees), medium-sized firms (50–249 employees), and large firms (250 or more employees). This classification is similar to the one adopted recently by the European Union. The industrial sectors are manufacturing, services and other industries including construction, mining, and energy and water supply.

2 Number and distribution of R&D firms supported by Tekes

2.1 Numbers of R&D firms and supported R&D firms

The enterprises having conducted R&D activities is the main reference group when the impact of public R&D funding on firm performance and job creation is to be analysed. *Table 1* gives the weighted number of firms conducting R&D activities in 1991, 1995 and 1998 according to R&D statistics, as well as the unweighted number of the supported firms based on Tekes payment data and R&D statistics. Firms have been classified to the group "supported" if they have (1) received R&D support payments from Tekes in the pertinent year *t*, or (2) used Tekes subsidies in their R&D activities in year *t*.

In Finland, the annual number of enterprises conducting R&D activities has varied approximately between 2,000 and 2,500 in the 1990s, covering about 1–2 per cent of the whole business enterprise sector. In the R&D statistics for 1991, the estimated number of R&D firms was 2,360. During the deep recession in the early 1990s, the number of R&D firms decreased, but increased soon after the recovery. In 1998, the estimated number of R&D firms was 2,193.[4]

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[4] The sampling frame of the R&D surveys does not cover micro firms, i.e. firms with less than 10 employees.

Table 1. Total number of R&D firms and number of R&D firms receiving R&D funding from Tekes in 1991, 1995 and 1998

	All R&D firms* Number of firms	%	Supported firms (1) Number of observations	%	Supported firms (2) Number of observations	%
1991						
Manufacturing						
-Small firms	1125	47.7	132	28.2		
-Medium-sized firms	625	26.5	69	14.7		
-Large firms	..	..	68	14.5		
Services						
-Small firms	473	20.0	142	30.3		
-Medium-sized firms	74	3.1	28	6.0		
-Large firms	..	..	5	1.1		
Other industries						
-Small firms	15	0.6	13	2.8		
-Medium-sized firms	48	2.0	3	0.6		
-Large firms	..	..	8	1.7		
Total number of firms	2360	100.0	468	100.0		
1995						
Manufacturing						
-Small firms	474	30.2	246	28.9		
-Medium-sized firms	309	19.7	110	12.9		
-Large firms	211	13.4	105	12.3		
Services						
-Small firms	407	25.9	287	33.7		
-Medium-sized firms	24	1.5	32	3.8		
-Large firms	28	1.8	16	1.9		
Other industries						
-Small firms	31	2.0	35	4.1		
-Medium-sized firms	64	4.1	9	1.1		
-Large firms	21	1.3	11	1.3		
Total number of firms	1569	100.0	851	100.0		
1998						
Manufacturing						
-Small firms	693	31.6	399	28.2	305	27.5
-Medium-sized firms	353	16.1	180	12.7	149	13.4
-Large firms	209	9.5	140	9.9	116	10.5
Services						
-Small firms	703	32.1	550	38.8	426	38.4
-Medium-sized firms	77	3.5	43	3.0	29	2.6
-Large firms	38	1.7	24	1.7	12	1.1
Other industries						
-Small firms	71	3.2	50	3.5	42	3.8
-Medium-sized firms	24	1.1	16	1.1	12	1.1
-Large firms	24	1.1	14	1.0	17	1.5
Total number of firms	2193	100.0	1416	100.0	1108	100.0

Notes: * R&D statistics 1991, 1995 and 1998. .. indicates not available.
(1) Tekes Register on R&D subsidies; (2) R&D statistics on R&D activities 1998.

When comparing the estimated proportions of the small and medium-sized service firms in 1995 and 1998, we can see that the proportions of these R&D firms are considerably higher in 1998 than in 1995. The opposite is true of the medium-sized and large manufacturing firms. In the same time period, the proportions of the small and medium-sized service firms, including the corresponding non-R&D firms, increased to a much lesser extent relative to all business firms (not shown in Table 1). In the 1991 R&D statistics, estimates were given for small firms (less than 50 employees) and for firms with 50–99, 100–499 or 500 or more employees. Concerning the year 1991, the estimated number of medium-sized R&D firms includes, thus, also the number of large R&D firms.

When we link the Tekes data on paid R&D support with data from the R&D surveys in 1991, 1995 and 1998, we find that the unweighted numbers of supported firms are 468, 851 and 1,416, respectively.[5] We also see that the number of supported small service firms has increased more from 1995 than that of small manufacturing firms has. According to R&D statistics, about 60 per cent of the small service R&D firms received R&D support from Tekes in 1998. The corresponding figure for the small manufacturing firms was about 45 per cent.[6]

2.2 Numbers and distribution of approved and rejected project proposals

In Section 2.1 we considered the weighted number of R&D firms and the unweighted number of the R&D firms that had (1) received R&D support payments from Tekes in the pertinent year *t*, or (2) used Tekes subsidies in their R&D activities in year *t*. In Section 2.3 we are going to consider the number of firms that applied for R&D support from Tekes in the 1990s. In this examination we do not use data from the

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[5] In the 1998 R&D statistics, the unweighted number of the firms using the subsidies granted by Tekes was 1,108. This number of supported firms is slightly smaller than the unweighted number of the firms to which Tekes paid a piece of R&D subsidy in 1998. However, we note that the proportions of the supported firms in the different size classes are quite consistent between R&D statistics (use data) and the Tekes Register (payment data).

[6] This observation derives partly from the sample design, which has not been a random one for the micro firms (and especially service firms) supported by Tekes and which has changed between the years 1991, 1995 and 1998. The sample designs are fairly similar for 1991 and 1993, 1995 and 1997 and then from 1998 onwards.

R&D surveys but merely from the Tekes Register and the Business Register. Before doing this it is, however, useful to look at the numbers and distribution of the applications for support.

The numbers of project proposals submitted to Tekes in the 1991 to 1998 period, as well as the numbers of approved and rejected applications are given in *Table 2*. These figures also include applications of some organisations other than firms. Table 2 shows that the approval rate of the applications has varied between 70 and 80 per cent in the 1990s. This figure is considerably high, which may partly be explained by the application process itself (see Lehtoranta, 2000, p. 35).

Table 2. Numbers of project proposals that have/have not received R&D support from Tekes in 1991 to 1998

Year	Number of projects	Approved	Rejected	Approval rate, %
1991	667	471	196	70.6
1992	794	572	222	72.0
1993	969	742	227	76.6
1994	869	665	204	76.5
1995	973	730	243	75.0
1996	1069	801	268	74.9
1997	1262	1025	237	81.2
1998	1132	901	231	79.6
Total	7735	5907	1828	76.4

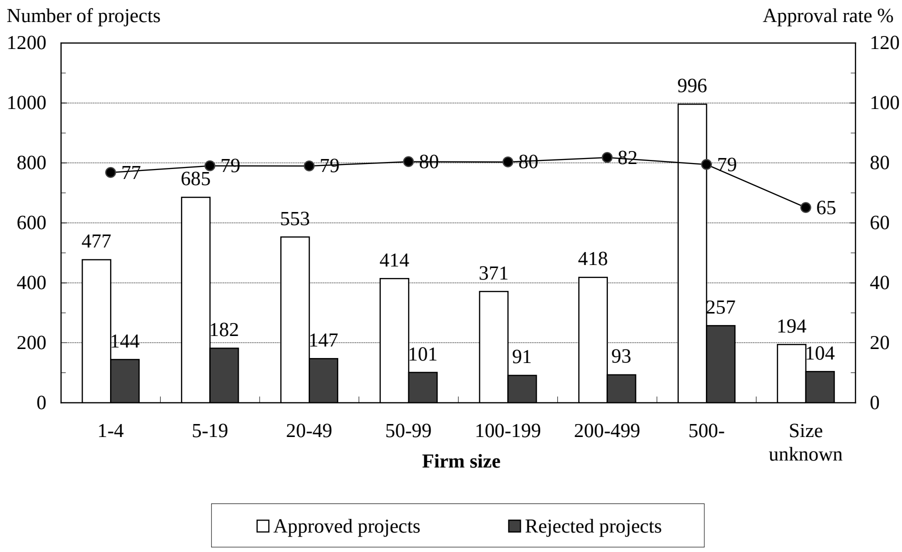
The number of project proposals submitted to Tekes increased from 667 to 1,132 in the 1991 to 1998 period. Over the same time span, the number of approved applications varied between 471 and 1,025, being highest in 1997. On average, the approved applications represent about 76 per cent of all the applications submitted to Tekes. The distribution of the approved and rejected applications by firm size is shown in *Figure 1*.[7] We

[7] When studying the numbers and distribution of the approved and rejected project proposals or firms in Figures 1–5, or in Appendix Figures A1–A2, we use the *approval data* in 1991 to 1998 from the Tekes Register linked only with the combined data of the annual statistical files of the Business Register in 1989 to 1998. Using this link allows us to exclude applicants that are not enterprises but associations, universities or research institutions.

can see that the average proportion of the approved projects relative to the total number of project applications does not vary a lot between the size groups, being between 77 and 82 per cent over the studied period. The largest firms (at least 500 employees) have the largest numbers of both applied and approved projects, followed by firms in the size groups of 5 to 19 and 20 to 49 employees (for further details, see Lehtoranta, 2000).

The distribution of approved and rejected projects by the industry of the firms concerned is shown in Appendix Figure A1. The largest numbers of supported (and also non-supported) projects are found in such technology-intensive industries as instruments, ADP services and technical consulting, but also in fabricated metals, non-electrical machinery and wholesale trade. The relatively high numbers of R&D projects in some of the service industries is an interesting feature with regard to the issues being considered in the next two chapters of this volume.

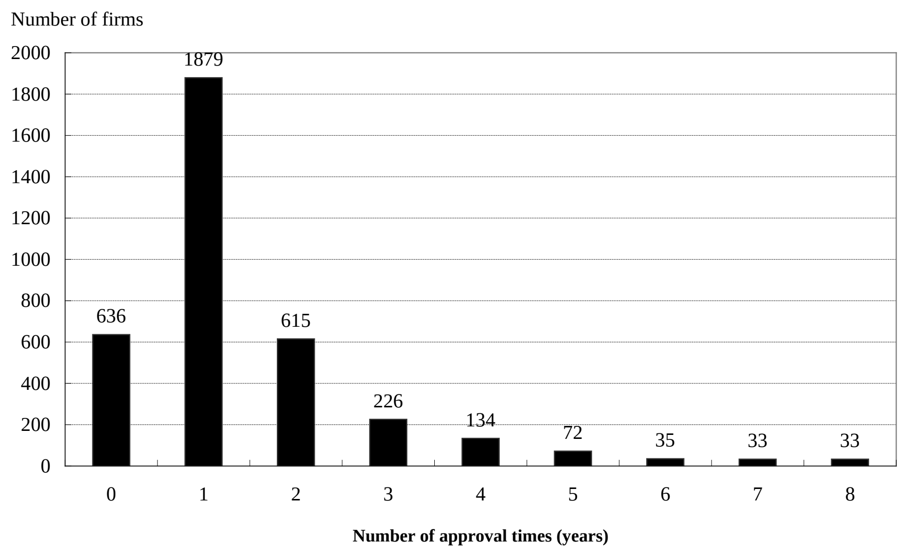
Figure 1. Numbers of projects that have/have not received R&D support from Tekes in 1991 to 1997 by size of firm



2.3 Number of firms that have applied for R&D support in the 1990s and proportion of regular applicants among them

In the 1991 to 1998 period, the total number of firms that applied for R&D subsidies from Tekes was 3,663. This number includes only those firms for which we can find a record in any of the annual statistical files of the Business Register in the period from 1989 to 1998. The number of firms for which at least one application was approved during the 1991 to 1998 period was 3,027. This number is about 83 per cent of the total number of firms that applied for R&D subsidies. All applications (mostly a single application) of 636 firms were rejected in the 1991 to 1998 period. Sixty per cent of this total were small firms with less than 5 employees and 70 per cent were firms with fewer than 10 employees. Fifty-three per cent of the rejected firms had started their operation in the 1990s.

Figure 2. Numbers of firms approved/not approved by Tekes in 1991 to 1998 by number of approval times



In *Figure 2*, we can see the numbers of the years in which at least one of a firm's applications was approved in the 1991 to 1998 period. The number varies from 0 (all applications were rejected) to 8 years (at least one application was approved each year from 1991 to 1998) and this describes the permanence profile of the Tekes custom. The majority (1,879), or 62 per cent, of the customer firms have had their applications approved in one single year only, while 33 firms, or 1 per cent, of the approved firms have received R&D support every year. The number of permanent clients (here firms that have received R&D support at least four times in eight years) is 307, which is about 10 per cent of all the approved firms. The majority of these firms are large firms. The firms that have been supported only once are mostly young, or just established. The total number of 3,663 firms which have applied for R&D support from Tekes in 1991 to 1998 includes 1,954 firms (53%) that were started up in the 1990s. The supported firms were, thus, mainly in their early stages.

2.4 Numbers and distribution of approved and rejected firms

The distribution by size of the approved[8] (3,027) and rejected (636) firms is shown in *Figure 3* (firm size is missing for 11 firms). The approval rate per firm is the lowest (75%) for the smallest firms (1–4 employees); about 85 per cent for the firms with fewer than 100 employees, on average, and about 90 per cent for the firms that have less than 500 employees. The approval rate is the highest (about 95%) for the largest firms. This figure is, however, affected by the fact that firms, and especially large firms, may have two or three applications per year. When we compare the approval rates at the project level, we see that they do not essentially vary between the different size classes, apart from that of the smallest firms, for which the approval rate of projects is somewhat smaller than that for the other firms (see Figure 1).

The distribution of the approved and rejected firms by industry is shown in Appendix Figure A2 (data on industry class is missing for 76 firms). The largest numbers of approved (as well as rejected) firms are found in technical consulting, ADP services, non-electrical machinery, wholesale trade and fabricated metals.

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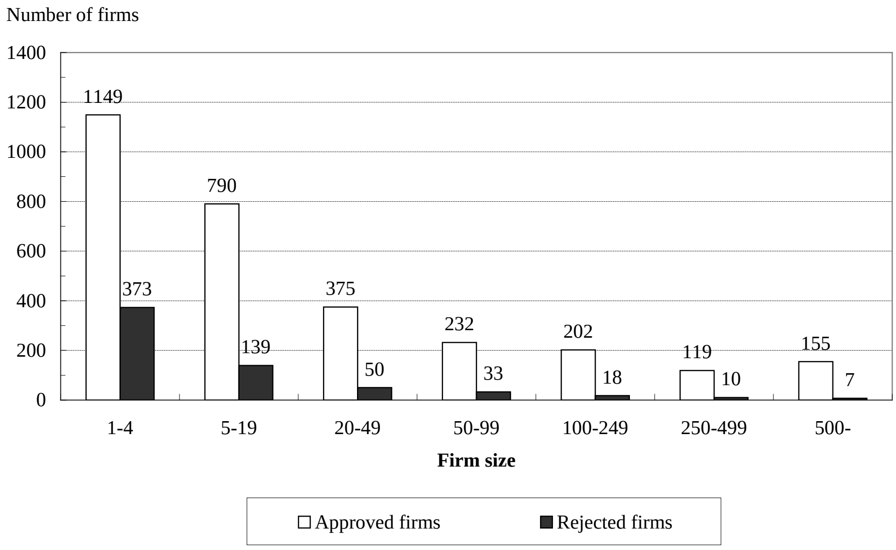
[8] Firms for which at least one application was accepted during the 1991 to 1998 period.

Figure 3. Numbers of firms that have/have not received R&D support from Tekes in 1991 to 1998 by size of firm



2.5 Growth patterns of approved firms in terms of turnover and number of employees

The combined turnover of the firms supported by Tekes in the 1991 to 1998 period amounts, on average, to 20 to 30 per cent of the total value of market production. In 1991, this share was 19.3 per cent, but it rose to close on 30 per cent after the mid-1990s. The growth patterns of the different cohorts of supported firms over the 1991 to 1998 period are shown in *Figure 4*. When comparing the median turnover between the cohorts (the first observation in each of the growth patterns) we find that it decreases slightly from one cohort to the next, indicating that the proportion of small supported firms relative to all supported firms has increased in the late 1990s.[9]

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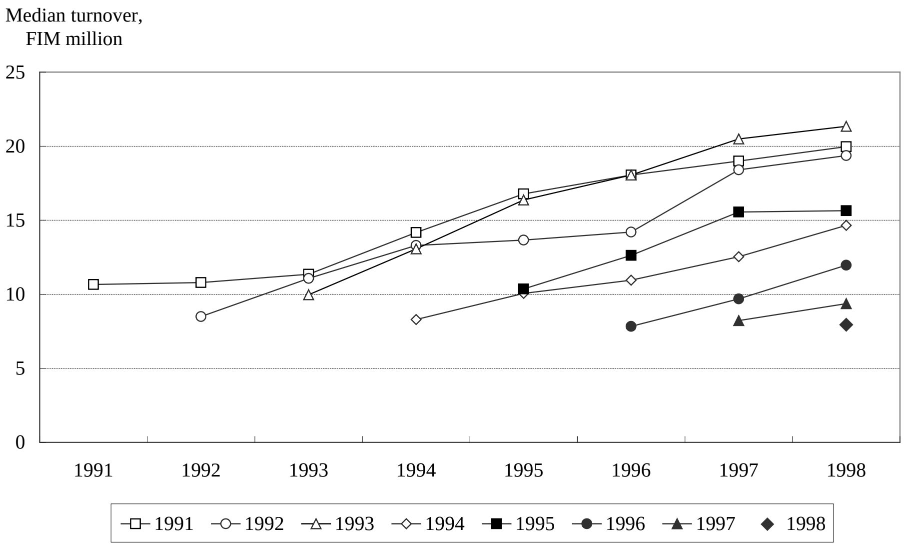
[9] Cohorts of firms, i.e. firms that have been approved in the same year, are here so constructed that each of them constitutes a balanced panel of firms belonging to that group. The figure did not change essentially even when we used non-balanced panels instead of balanced ones. The turnover of firms is measured at current prices, at fixed prices the median turnover would diminish even more clearly between cohorts.

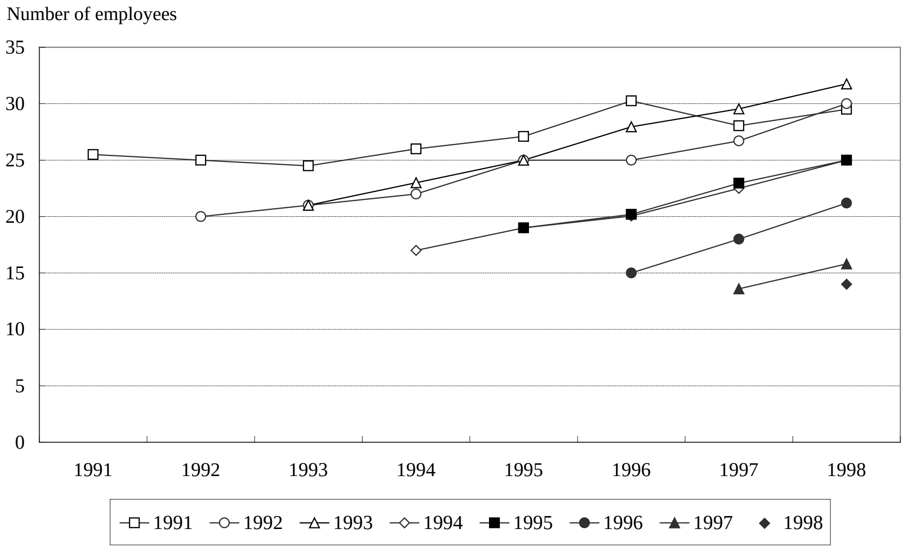
Figure 4. Growth patterns of different cohorts of firms supported by Tekes in 1991–1998 in terms of median turnover



When considering the growth patterns of consecutive cohorts we find that the average annual growth rates of sales over the first three years after a supporting decision have increased from one cohort to the next, but not until since the year 1994. The same is true of the average turnover of the supported firms from 1993 onwards (not shown in Figure 4) and of the median (and average) number of employees (Figure 5). This observation may be explained by the economic recovery after the deep recession of the early 1990s, but it may also be due to the changing cohort characteristics.

The median number of employees in the supported firms tells us the same story as the median turnover does: the proportion of small supported firms relative to all supported firms has increased in the late 1990s. It is probable that the extra R&D funding programme channelled through Tekes in 1997–1999 has contributed to this change by shifting the focus to SMEs to a larger extent than before. In 1991, the median number of personnel in the firms supported by Tekes was 25.5, but in 1998 the number was down to no more than 14. The total number of employees in the supported firms accounted for between 8.5 per cent (in 1991) and 14.4 per cent (in 1998) of the total number of employees in market production. The growth patterns of the different cohorts of the firms supported in the 1991 to 1998 period in terms of median numbers of employees are shown in *Figure 5*.

Figure 5. Growth patterns of different cohorts of firms supported by Tekes in 1991–1998 in terms of median numbers of employees

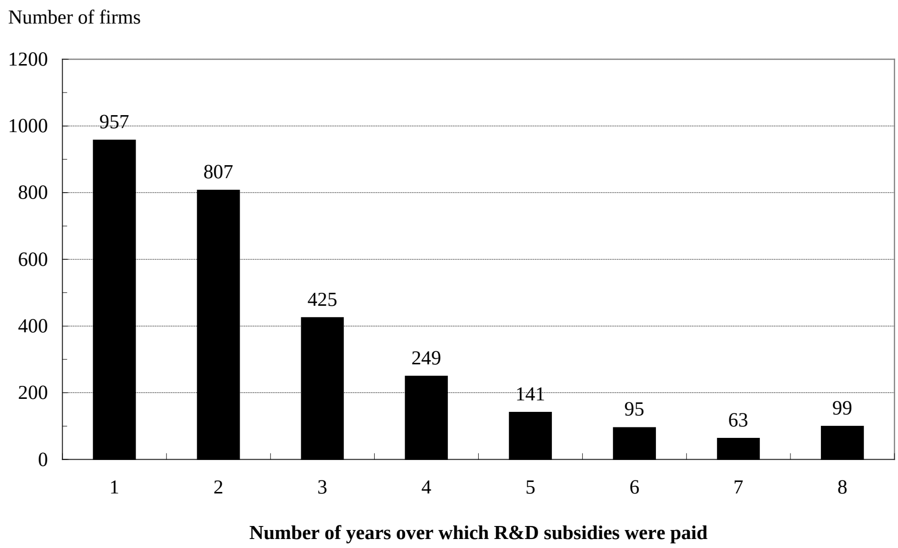


2.6 Numbers and distribution of firms to which subsidies were paid by Tekes

During the 1991 to 1998 period, Tekes paid R&D subsidies (either a loan or a direct subsidy, or both) to 2,836 firms. Again, this figure only includes those firms on which we have a record in some annual statistical file of the Business Register over the 1989 to 1998 period. The payments of a loan or direct subsidy may be apportioned to different calendar years and, in many cases, payments are recorded to a year other than the one to which the decision to grant the support is recorded. The full payment event relating to a financing decision includes many (usually sequential) yearly events. This is one reason why the number of the firms to which subsidies have been paid during a certain period is smaller than the number of the firms for which R&D support has been approved (3,027 firms).

Figure 6 shows that the paid R&D support is, indeed, distributed over many years. One-third of those firms for which R&D subsidies were paid by Tekes in the 1991 to 1998 period received these payments during one year only, about 30 per cent received them over two years and 15 per cent over three years. Between 5 and 10 per cent of the supported firms received the R&D subsidies during four or five years.

Figure 6. Numbers of firms to which R&D subsidies were paid by Tekes in 1991–1998 by number of years over which payments were made



The reason for examining the breakdown of the R&D subsidies over years is that it may influence the analysis concerning the impact of these subsidies. As already pointed out, all payments of R&D subsidies for a project should be taken into account where the impact of public R&D support is to be analysed on the cash basis. In Section 3 we have defined a firm as "supported" if Tekes has paid to it an item of R&D subsidy in the year under consideration or over the two years preceding it. The payment data include 1,443 firms (51%) which had started their operation in the 1990s. This definition does not exclude cases where a "non-supported" firm has received a considerable payment of R&D support four or five years ago, for example. However, we have discovered that the observation period of payments does not affect the results significantly if we only examine whether there are noticeable differences between the supported and non-supported firms in general.

3 Basic characteristics of supported and non-supported firms

Based on the data sources described in Section 1 and illustrated in Section 2, some key characteristics of the various groups of firms are presented here in Section 3. Each of the tables compares the performance measures for the firms having and not having received R&D support from Tekes classified according to size and industrial sector. The size groups are small firms (less than 50 employees), medium-sized firms (50–249 employees), and large firms (250 or more employees). Here we consider only the manufacturing and services sectors.

Table 3 gives an account of the labour productivity (defined as value added/employee) levels for the various groups of firms. The productivity levels concern the years 1989, 1993 and 1997. Firms have here been classified into the "supported" group if they have received R&D support in the year *t*–2, *t*–1 or *t*.

From the table we see that, in otherwise similar sectors and size groups, the firms receiving support have higher productivity levels than those not receiving support. The only exception is small service firms in 1997: the non-supported service firms show higher productivity levels. The same applies to the year 1996 (not shown in Table 3). There is also a lot of variation in the productivity levels of the firms differing in size and industrial sector. In manufacturing, and in the group of non-supported service firms, large firms are more productive than small ones but, interestingly, this seems not to be the case in the group of supported service firms.

Table 4 shows the relative changes in the labour productivity over three periods, 1986–1988, 1992–1994 and 1994–1996. The productivity levels concern the years 1986, 1988, 1992, 1994 and 1996. The "supported" group refers here to the years *t*–4, *t*–3 and *t*–2. For example, in the 1994 to 1996 period, the firms which had received R&D support in 1992, 1993 or 1994 have been classified as "supported". Otherwise, they have been classified as "non-supported". The size of a firm is here calculated as the mean of its number of employees in two consecutive years.

Table 3. Average labour productivity (value added/person) in 1989, 1993 and 1997, of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		Supported firms		
	Number of observations	FIM 1000	Number of observations	FIM 1000	
1989		(1)		(2)	(2)/(1)
Manufacturing					
-Small firms	627	154.8			
-Medium-sized firms	540	163.5			
-Large firms	237	197.4			
Services					
-Small firms	1261	170.9			
-Medium-sized firms	369	196.8			
-Large firms	138	210.6			
Total number of firms	3172				
1993					
Manufacturing					
-Small firms	546	174.3	32	186.0	1.07
-Medium-sized firms	399	194.0	95	218.3	1.13
-Large firms	127	248.6	100	283.7	1.14
Services					
-Small firms	2378	187.7	32	261.4	1.39
-Medium-sized firms	400	237.0	32	265.6	1.12
-Large firms	125	241.3	8	248.6	1.03
Total number of firms	3975		299		
1997					
Manufacturing					
-Small firms	1517	225.9	222	235.8	1.04
-Medium-sized firms	567	260.6	198	277.0	1.06
-Large firms	108	317.3	154	337.3	1.06
Services					
-Small firms	3159	270.2	186	221.2	0.82
-Medium-sized firms	646	281.7	36	316.4	1.12
-Large firms	149	290.3	19	309.2	1.07
Total number of firms	6146		815		

From Table 4 we can see that productivity growth was higher in the supported than in the non-supported small and medium-sized firms. This tendency increased among the service firms in the 1994 to 1996 period. With the supported manufacturing firms, on the other hand, the

Table 4. Average changes in labour productivity (value added/person), %, in 1986 to 1988, 1992 to 1994 and 1994 to 1996 of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		Supported firms		
	Number of observa-tions	%	Number of observa-tions	%	
1986 to 1988		a		b	(100+b)/ (100+a)
Manufacturing					
-Small firms	379	23.4			
-Medium-sized firms	404	29.3			
-Large firms	191	32.4			
Services					
-Small firms	950	26.6			
-Medium-sized firms	327	33.0			
-Large firms	141	37.9			
Total number of firms	2392				
1992 to 1994					
Manufacturing					
-Small firms	408	17.6	19	18.4	1.01
-Medium-sized firms	345	26.6	63	28.9	1.02
-Large firms	127	23.4	79	21.3	0.98
Services					
-Small firms	1399	8.8	15	12.9	1.04
-Medium-sized firms	341	28.1	16	30.0	1.01
-Large firms	116	25.6	5	22.5	0.98
Total number of firms	2736		197		
1994 to 1996					
Manufacturing					
-Small firms	882	16.6	90	14.3	0.98
-Medium-sized firms	399	16.6	108	9.6	0.94
-Large firms	101	11.0	109	9.5	0.99
Services					
-Small firms	975	2.6	72	16.1	1.13
-Medium-sized firms	362	10.1	25	22.6	1.11
-Large firms	110	3.7	13	-1.7	0.95
Total number of firms	2829		417		

growth of productivity slowed down compared to that of the non-supported ones. With large firms, productivity growth was persistently higher among the non-supported ones. The supported large service firms even had a negative productivity development in the 1994 to 1996 period. Negative productivity development is possible, for example, at the early stages of R&D and also in relatively new firms, when new employees are recruited but the results of the research have not yet led to productivity-improving products or production processes. However, the number of the supported large service firms is fairly small, and it is difficult to draw general conclusions here.

The technology intensities of the various types of firms are looked at next. *Table 5* gives the total R&D expenditure and privately financed R&D expenditure[10] as a proportion of turnover. Here we consider the years 1991, 1993 and 1995 because the R&D surveys in these years had a greater coverage than in other years. The group "supported" refers to firms that have received R&D support from Tekes in the year *t*–3, *t*–2 or *t*. We have excluded from the consideration the firms with an R&D intensity of over 50 per cent, because we were not able to check the consistency of their R&D expenditure with their turnover in the combined database (see Lehtoranta, 1999, p. 14).

The total R&D intensities of the supported firms are considerably higher than those of the non-supported ones in the corresponding size and sector groups. The average R&D intensity has increased especially in the group of small, supported service firms. The proportion of R&D expenditure financed by the private sector has increased, too. However, when comparing the different years, we have to take into account that the samples on which Table 5 is based were very dissimilar in 1993 and 1995. In 1995, we also used turnover data on small service firms derived from the Business Taxation Register. This data source on small firms was not available to us concerning the year 1993.

The total R&D intensity of the supported firms seems to systematically decrease as the firm size increases, and more strongly with service firms than with manufacturing ones. The year 1991 is an exception, but the number of supported service firms was fairly small then. The differences are less pronounced when examining the privately financed, instead of the total, R&D intensity. The amount of public R&D funding plays a bigger role relative to the turnover for small firms than for large ones.

The average capital intensity (capital stock per employee) shows huge variations across the different groups of firms (*Table 6*). The general observation is that capital intensity increases along with firm size.

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[10] Financed by the private sector, i.e. by firms themselves, firms in the same group or by other domestic firms.

The supported service firms in the recession year 1993 make an exception to this. However, the number of these firms was fairly small in 1993. Except for the small and medium-sized service firms in 1997, the average capital intensity of the supported firms is higher than that of the non-supported ones. The same applies to the year 1996, but not to earlier years (not shown in Table 6).

Table 5. Average total R&D expenditure/turnover and privately financed R&D/turnover in 1991, 1993 and 1995, %, of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		Supported firms		
	Number of observations	Total R&D	Number of observations	Total R&D	Privately financed R&D
1991					
Manufacturing					
-Small firms	451	0.7	13	6.1	2.4
-Medium-sized firms	326	0.9	33	5.1	4.1
-Large firms	146	1.3	58	3.6	3.2
Services					
-Small firms	139	0.8	5	5.1	3.7
-Medium-sized firms	73	1.2	11	14.5	11.2
-Large firms	22	0.9	3	1.8	1.4
Total number of firms	1157		123		
1993					
Manufacturing					
-Small firms	447	0.4	23	5.2	4.4
-Medium-sized firms	311	0.7	73	3.2	2.6
-Large firms	112	1	86	2.5	2.3
Services					
-Small firms	141	1.7	16	5.5	3.7
-Medium-sized firms	74	0.9	25	5.4	4.5
-Large firms	20	1.3	8	5.4	4.7
Total number of firms	1105		231		
1995					
Manufacturing					
-Small firms	631	1.8	116	7.2	4.5
-Medium-sized firms	265	1.2	123	4.1	3.4
-Large firms	98	0.9	123	2.7	2.4
Services					
-Small firms	263	6.1	82	16.6	9.6
-Medium-sized firms	55	1.5	20	5.3	4.3
-Large firms	19	2.1	13	5.4	4.8
Total number of firms	1331		477		

It seems that there has been a change in the incidence of R&D support relating to service companies and evidently associated with the development of new information technologies. On average, the supported service firms have now lower capital intensity, but higher technology intensity, than they had in the early 1990s. The number and proportion of service firms and, especially firms in industries like software services,

Table 6. Average capital stock/employee in 1989, 1993 and 1997 of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		Supported firms		
	Number of observa-tions	FIM 1000	Number of observa-tions	FIM 1000	
1989		(1)		(2)	(2)/(1)
Manufacturing					
-Small firms	623	65.7			
-Medium-sized firms	540	79.9			
-Large firms	237	112.5			
Services					
-Small firms	987	30.0			
-Medium-sized firms	306	74.0			
-Large firms	112	86.3			
Total number of firms	2805				
1993					
Manufacturing					
-Small firms	551	79.3	33	140.2	1.77
-Medium-sized firms	395	103.9	95	132.8	1.28
-Large firms	127	197.0	100	222.3	1.13
Services					
-Small firms	2182	31.9	37	82.4	2.58
-Medium-sized firms	371	62.1	35	94.7	1.53
-Large firms	116	94.1	9	68.4	0.73
Total number of firms	3742		309		
1997					
Manufacturing					
-Small firms	1508	80.8	229	86.9	1.08
-Medium-sized firms	562	116.3	197	135.8	1.17
-Large firms	108	195.6	154	243.5	1.24
Services					
-Small firms	3175	47.8	188	41.1	0.86
-Medium-sized firms	632	76.8	40	63.8	0.83
-Large firms	150	105.5	19	184.4	1.75
Total number of firms	6135		827		

technical consulting and R&D services, have increased considerably in the group of supported firms. The highest increase occurred in 1997, but the change is visible already in 1996 (see Appendix Table A1).

Table 7. **Number of domestic patent applications per firm in 1989, 1993 and 1996 of firms receiving and not receiving R&D funding from Tekes**

	Non-supported firms		Supported firms	
	Number of observa-tions	Patents per firm	Number of observa-tions	Patents per firm
1989				
Manufacturing				
-Small firms	628	0,01		
-Medium-sized firms	540	0,09		
-Large firms	237	2,57		
Services				
-Small firms	1479	0,00		
-Medium-sized firms	372	0,01		
-Large firms	138	0,01		
Total number of firms	3394			
1993				
Manufacturing				
-Small firms	556	0,02	33	0,06
-Medium-sized firms	400	0,10	95	0,32
-Large firms	127	0,64	100	5,30
Services				
-Small firms	2759	0,00	39	0,67
-Medium-sized firms	403	0,02	36	0,28
-Large firms	125	0,02	9	0,67
Total number of firms	4370		312	
1996				
Manufacturing				
-Small firms	1588	0,03	201	0,12
-Medium-sized firms	564	0,07	165	0,41
-Large firms	108	0,42	148	4,18
Services				
-Small firms	3477	0,01	200	0,13
-Medium-sized firms	613	0,01	38	0,40
-Large firms	141	0,01	18	3,44
Total number of firms	6491		770	

Table 7 gives the number of domestic patent applications per firm in 1989, 1993 and 1996. We consider here, as well as in Table 8, the year 1996 instead of 1997, because the number of patenting firms in

1997 was not available to us. There is a lot of variation in the patenting behaviour of the studied firms. Generally, the supported firms patent substantially more than the non-supported ones do. This is not surprising in view of the fact that the supported firms are, on average, much more technology-intensive (see Table 5).

Table 8. Number of US patents per firm in 1989, 1993 and 1996 of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		Supported firms	
	Number of observations	Patents per firm	Number of observations	Patents per firm
1989				
Manufacturing				
-Small firms	628	0,00		
-Medium-sized firms	540	0,01		
-Large firms	237	0,52		
Services				
-Small firms	1479	0,00		
-Medium-sized firms	372	0,00		
-Large firms	138	0,00		
Total number of firms	3394			
1993				
Manufacturing				
-Small firms	556	0,00	33	0,03
-Medium-sized firms	400	0,01	95	0,06
-Large firms	127	0,19	100	1,39
Services				
-Small firms	2759	0,00	39	0,10
-Medium-sized firms	403	0,01	36	0,39
-Large firms	125	0,00	9	0,44
Total number of firms	4370		312	
1996				
Manufacturing				
-Small firms	1588	0,01	201	0,02
-Medium-sized firms	564	0,01	165	0,08
-Large firms	108	0,01	148	1,58
Services				
-Small firms	3477	0,00	200	0,03
-Medium-sized firms	613	0,01	38	0,37
-Large firms	141	0,01	18	0,28
Total number of firms	6491		770	

The most striking difference in patenting frequency is between the large non-supported and supported firms, both in manufacturing and services. The large manufacturing firms still keep their distinct leading role when considering the number of patents granted in the United States (*Table 8*).

Table 9. Average proportions of employees with tertiary education in engineering and natural sciences in 1989, 1993 and 1997 of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms		**Supported firms**		
	Number of observations	**%**	**Number of observations**	**%**	
1989		**a**		**b**	**(100+b)/ (100+a)**
Manufacturing					
-Small firms	599	2.6			
-Medium-sized firms	533	3.6			
-Large firms	236	5.5			
Services					
-Small firms	97	2.5			
-Medium-sized firms	68	5.3			
-Large firms	48	5.7			
Total number of firms	1581				
1993					
Manufacturing					
-Small firms	527	4.4	33	15.2	1.10
-Medium-sized firms	398	5.0	95	11.9	1.07
-Large firms	127	5.4	100	11.1	1.05
Services					
-Small firms	246	19.6	25	35.3	1.13
-Medium-sized firms	141	15.2	33	36.2	1.18
-Large firms	51	8.3	9	36.7	1.26
Total number of firms	1490		295		
1997					
Manufacturing					
-Small firms	1370	6.3	212	19.0	1.12
-Medium-sized firms	537	6.5	186	13.2	1.06
-Large firms	103	7.6	150	11.7	1.04
Services					
-Small firms	616	20.5	150	42.4	1.18
-Medium-sized firms	196	14.4	35	40.4	1.23
-Large firms	50	8.0	15	19.5	1.11
Total number of firms	2872		748		

The average proportions in 1989, 1993 and 1997 of employees with tertiary level education in engineering and natural sciences are shown in *Table 9*. Strikingly, the proportions favour service firms and, especially, the supported ones. This observation derives partly from the fact that there are more blue-collar workers in manufacturing firms than in service firms, but there is also evidence that high knowledge spillovers support large investment in R&D and competencies in services but reduce them in manufacturing.[11] Maintenance of a high knowledge level is even more crucial for innovating service firms than for innovating manufacturing firms. We also know that the supported projects are commonly selected on the basis of their potential profitability, the innovativeness of the concept and the R&D skills of the firm applying for support.[12]

The average product and process innovativeness of manufacturing and service firms in the 1994 to 1996 period is shown in *Table 10*. These figures are based on the 1996 Community Innovation Survey (CIS 2) of Statistics Finland and they describe the unweighted numbers of those non-supported and supported firms which stated that they had introduced innovations in the years 1994 to 1996. The data on the R&D support are taken from Tekes payment data for the years 1994, 1995 or 1996.

Table 10. Average product and process innovativeness in the 1994 to 1996 period of firms receiving and not receiving R&D funding from Tekes

	Non-supported firms			Supported firms		
	Number of observations	Product innovat. share	Process innovat. share	Number of observations	Product innovat. share	Process innovat. share
1994 to 1996						
Manufacturing						
-Small firms	504	15.1	14.5	39	69.2	41.0
-Medium-sized firms	302	25.5	23.5	79	64.6	43.0
-Large firms	79	53.2	44.3	114	80.7	66.7
Services						
-Small firms	323	18.3		17	100.0	
-Medium-sized firms	156	30.8		10	50.0	
-Large firms	55	38.2		7	85.7	
Total number of firms	1419			266		

[11] See Leiponen (2000).

[12] See Lehtoranta (2000, p. 11).

The proportion of innovating firms is considerably higher among the supported firms than among the non-supported ones. Two-thirds of the supported small or medium-sized manufacturing firms replied that they had introduced new products in 1994 to 1996 and about 40 per cent had introduced new production processes. All the small supported service firms declared that they had introduced new products (services) in 1994 to 1996. One-half of the medium-sized supported service firms had introduced new services. However, the number of the supported service firms is fairly small, and it is difficult to draw general conclusions here.

Table 10 does not give us the effectiveness of the R&D support. Instead, it describes the different time lags from the receipt of financial support to the market introduction of an innovation in manufacturing and services. In services, this time lag is clearly shorter than in manufacturing and this is obviously one reason why a considerably high proportion of the service firms declared that they had introduced product innovations within the examined time period. In addition, the characteristics of these innovations differ in many cases from those in manufacturing.[13] However, it comes as no surprise that the firms that have been supported in the 1994 to 1996 period have introduced more innovations than the non-supported ones have. Interestingly, the proportion of the firms that have introduced innovations increases with firm size, except for the smallest supported firms.

4 Concluding remarks

An examination of the incidence of the R&D support provided by Tekes reveals that the number and proportion of small firms, and especially service firms in industries like information technology, technical consulting and R&D services, has increased considerably in the group of supported firms after the mid-1990s. It is probable that the extra R&D funding programme channelled through Tekes in the 1997 to 1999 period shifted the focus to SMEs to a larger extent than before even though the change was visible already in 1996.

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[13] Service firms may, for instance, declare that they have commercialised innovations developed by other firms.

Although the number and proportion of small firms have increased among the recipients of R&D support, the largest firms still have the largest numbers of both applied and approved projects and they receive the largest amounts of support per firm. At the project level there are, however, no big differences in the approval rates between the different size classes. The approval rates vary more between the industrial sectors.

There is quite a lot of variation in the performance of firms in the 1989 to 1998 period, when they are compared in terms of size, industrial sector and the use or non-use of public R&D support.[14] In spite of this, some general observations can be made about the performance of the supported firms versus the non-supported ones. The firms receiving support have, on average, higher productivity levels than those not receiving have, except for the small service firms.[15] The growth of productivity is higher in the supported than in the non-supported small and medium-sized firms. This tendency strengthened among service firms and weakened among manufacturing firms in the 1994 to 1996 period. Among the large firms, the growth of productivity is persistently higher for the non-supported firms.

The total R&D intensities of the supported firms are considerably higher than those of the non-supported ones, especially in the group of supported small service firms. The average capital intensity of the supported firms is higher than that of the non-supported ones, except for the small and medium-sized service firms.

The supported firms patent substantially more than the non-supported ones do. The most striking difference in the patenting frequency is between the large supported and non-supported firms, both in manufacturing and services. The high proportion of employees with tertiary level of education in engineering and natural sciences is especially characteristic of the supported service firms. The proportion of innovating firms is considerably higher among the supported firms than among the non-supported ones. By innovating firms we mean

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14 The use of public R&D support is here approximated with data on the R&D funding paid by Tekes in the years *t*–2, *t*–1 and *t* (in Table 4, in the years *t*–4, *t*–3 and *t*–2). In Table 1 we examined the numbers of the firms to which R&D support was paid by Tekes during the pertinent year *t*. Consequently, the meaning of the term "supported" is slightly different in this table. Data from annual R&D surveys on the use of all public R&D support were used in Table 5.

15 The group "non-supported" firms here also includes firms that have not applied for support.

here firms that have introduced new products (services) or production processes in the 1994 to 1996 period.

In Lehtoranta (2000), an approach was adopted in which the data on R&D subsidies in the Tekes Registers were exploited for the purpose of assessing the impact of public R&D funding on the profitability and growth performance of firms. However, it is easy to conclude here that more research should be done on this topic. Especially an analysis of the effects of a specified R&D project, or several R&D projects, on the performance of the firms that have been supported still awaits implementation. Admittedly, this is not an easy task in respect of the firms starting operation after they have had their application approved, but examining already established firms, on which some relevant information is available, is quite feasible. The analysis should consider the firms' performance before and after the approval of a project and also take into account other factors and characteristics affecting their performance.

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Appendix of Chapter 2

Table A1. Numbers of firms that have received R&D support from Tekes in 1991 to 1998 by approval year and industry of firm

TOL95	Industry	1991	1992	1993	1994	1995	1996	1997	1998*	Total
15	Food & Beverages	5	4	15	17	33	28	23	22	147
17	Textiles	3	6	5	5	3	7	6	11	46
18-19	Clothes	0	1	3	6	4	3	3	3	23
20	Wood processing	7	9	9	17	20	27	29	27	145
21	Pulp & Paper	9	11	9	9	16	10	12	6	82
22	Printing	1	6	4	3	11	10	7	5	47
23-24	Chemicals	18	16	21	18	22	23	27	29	174
25	Plastics & Rubber	8	10	17	10	18	13	27	21	124
26	Non -Metallic Products	9	7	14	22	20	21	13	17	123
27	Basic Metals	9	8	14	6	13	6	10	7	73
28	Fabricated Metals	17	20	42	28	38	37	53	42	277
29	Non-electric Machinery	47	76	92	85	76	84	105	93	658
30-31	Computers & Electr. Machinery	14	21	24	24	16	19	30	27	175
32	Electronics	17	23	32	20	18	29	28	22	189
33	Instruments	32	38	48	45	36	46	61	42	348
34	Cars	4	3	13	5	7	6	9	7	54
35	Ship, Aircraft & Rail Motor Veh.	7	6	8	7	19	9	10	5	71
36-37	Furniture	3	11	16	13	12	10	26	17	108
40-45	Elect., Water supply & Construction	14	26	29	30	37	28	42	43	249
50,52	Retail trade	3	3	5	3	3	5	10	9	41
51,55	Wholesale trade & Restaurants	19	27	39	35	39	38	69	48	314
60-63	Transport	0	2	1	1	3	1	5	8	21
64	Telecommunication	0	3	3	1	6	5	9	5	32
65-67	Banking & Finance	1	1	1	2	2	3	2	3	15
70-71	Real estate business	7	4	7	9	7	6	5	11	56
72	ADP services	43	56	58	58	56	77	106	79	533
73	Research and Development	8	6	14	14	15	16	24	26	123
741	Holding Companies	23	21	19	19	22	29	35	28	196
742	Technical Consulting	44	55	72	62	66	76	109	91	575
743-748	Other business services	7	5	12	5	12	20	24	23	108
75-85	Public services	3	1	5	3	1	4	7	8	32
90-93	Other services	10	17	13	17	20	20	13	18	128
1-14	Others	5	4	4	5	5	11	12	12	58
	Industry unknown	19	8	7	4	2	2	1	0	43
	Total	416	515	675	608	678	729	952	815	5388

Note: * All approved firms are not included here: there is a time lag in the rate at which new firms are included in the annual statistical files of the Business Register.

Figure A1. Numbers of projects that have/have not received R&D support from Tekes in 1991 to 1997 by industry of firm

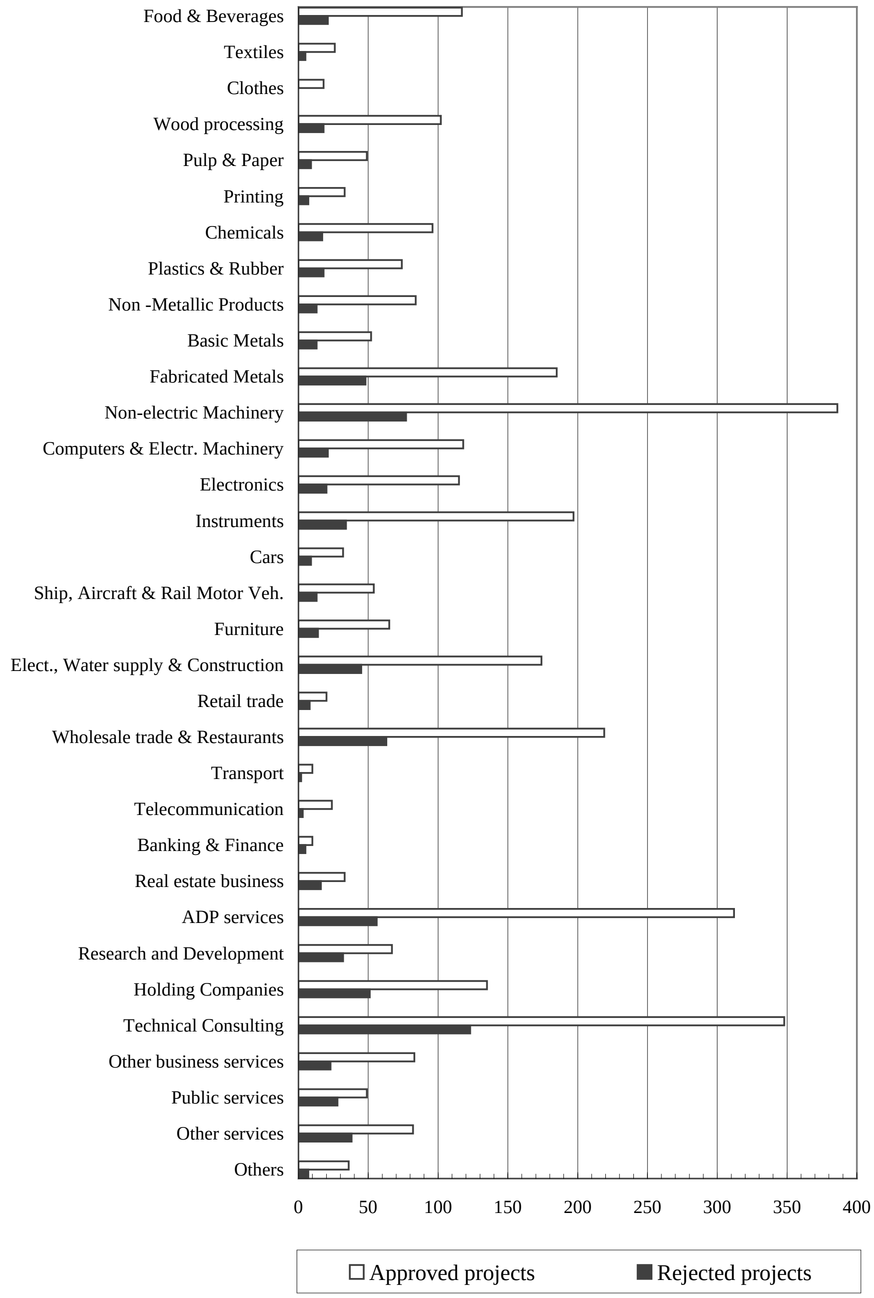
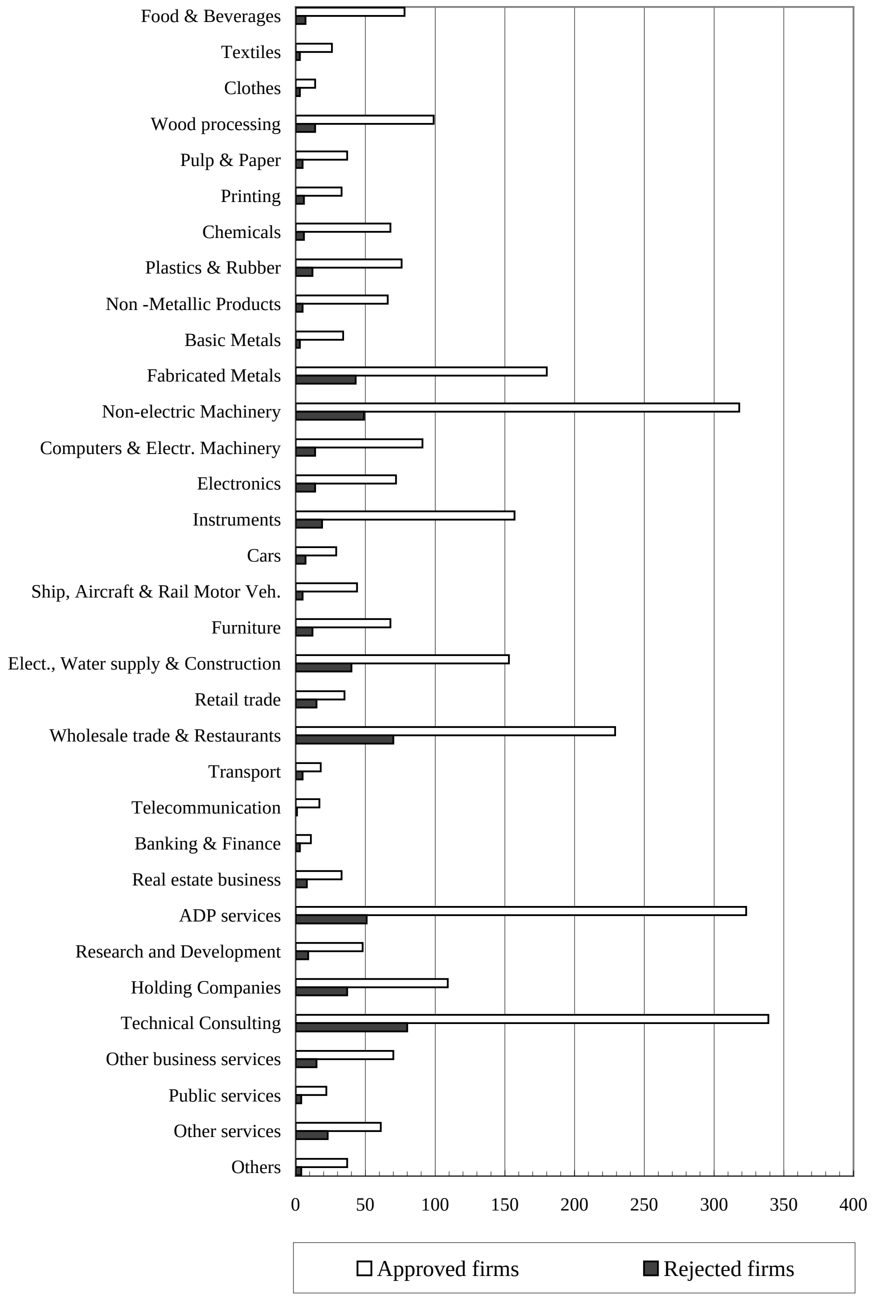


Figure A2. Numbers of different firms that have/have not received R&D support from Tekes in 1991 to 1998 by industry of firm



Chapter 3

PRIVATELY AND PUBLICLY FINANCED R&D AS DETERMINANTS OF PRODUCTIVITY – EVIDENCE FROM FINNISH ENTERPRISES

Mika Maliranta

Acknowledgements: Data work and estimations have been carried out at Statistics Finland following the terms and conditions of confidentiality. I would like to thank especially Merja Kiljunen for valuable help in constructing the data sets for the analysis. Acknowledgements for helpful comments are due to Rita Asplund and Petri Rouvinen. Of course, I am solely responsible for the conclusions and any remaining errors.

1 Introduction

The sustained increase of aggregate output per labour input, i.e. the evolution of aggregate productivity, is the ultimate source of the growth of a nation's living standards. Productivity improves as new and better technologies are created and adopted and when firms manage to improve the utilisation of the production possibilities that are determined by the available technology.[1] The level of technology as well as the ability to use it efficiently, both of which determine productivity, are also major factors behind the competitiveness of a firm.

In this study we investigate how R&D efforts are reflected in the productivity growth of firms. We examine the impact of privately and publicly financed R&D expenditures as well as the total R&D expenditures in the industry on the firm's productivity. Our analysis covers firms in manufacturing, services and other industries (construction, mining and electricity) and explores whether there are differences between the three sectors. More specifically, we address the question of whether the return on R&D inputs in terms of productivity is the same in manufacturing, services and other sectors. The analysis is based on a data set that is constructed by linking several distinct data sources such as the R&D survey data, Financial Statements data, Innovation Survey data and Employment Statistics (for details, see Appendix 1 of this chapter).

The main objective of our analysis is to examine whether there are significant differences in the effect of R&D effort on productivity by the source of R&D funding.

To see why it is important to study the role of privately and publicly financed R&D investments for productivity it is useful to look at the past and the current level of productivity performance in Finnish manufacturing from an international perspective. *Figure 1* below shows the level of total factor productivity in Finnish manufacturing compared to that of Sweden and the United States since the early 1980s. According

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1 The usefulness of an approach where productivity growth is divided into two distinct components has been emphasised by Färe et al. (1994), Pohjola (1996) and recently also by Koop et al. (1999). The first component is the shift of the production frontier, which indicates the maximum technically feasible output with given inputs. The second component, the change of the distance from the frontier, indicates the change of (in)efficiency.

to several studies[2], the United States has traditionally been the productivity leader. The figure shows that during the last two decades the productivity performance of Finnish manufacturing has moved close to that of the international top group.

Referring to the discussion above, two different interpretations for the superior productivity growth performance in Finland can be put forth. One interpretation is that technological progress has been more rapid in Finland than in Sweden or the United States. Alternatively we may assume that in each country agents operate according to a common technology, and deviations from the maximum output-to-input-ratio at a given point of time indicate inefficiency in the usage of inputs. This perspective on productivity growth suggests that a low productivity level is a symptom of the inability to use inputs efficiently.

A distinction between different sources of productivity growth may be argued to be of great importance when pondering the prospects of future growth, but also from the view of policy considerations. It may be easier to eliminate inefficiencies than to enhance technical progress. In a situation where the potential for extra growth due to inefficiencies has been more or less exhausted, it might seem difficult to continue along the same path in the future. Furthermore, the optimal policy action is likely to vary depending on whether the country (or a firm) is efficient or whether it is on (or close to) the production frontier.

One suggestive message mediated by the figure is that Finnish manufacturing has shifted from being an imitating follower to a sector that is shifting the international production frontier. It is, however, worth reminding ourselves that the figure hides a lot of variation across manufacturing industries and firms using different technologies. An industry-level analysis reveals that the total factor productivity level in the Finnish food industry was about two-thirds of that in the USA. On the other hand, in the paper industry and basic metals Finland seems to have overtaken the US level and is in these industries nowadays clearly superior in terms of productivity (see Statistics Finland, 2000).

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[2] See for example Baumol et al. (1989), van Ark and Pilat (1993) and McKinsey Global Institute (1993, 1996).

Figure 1 . The relative total factor productivity level of Finnish manufacturing from 1980 to 1996, USA=100

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other types of printers.

Note: The figure is based on updated results from Maliranta (1996). The productivity comparisons have been made by using the same approach as in the ICOP (International Comparisons of Output and Productivity) project at the Groningen university (see van Ark and Pilat, 1993). In this so-called industry-of-origin approach value added figures are converted into a common currency by using unit value ratios. These ratios have been calculated for the binary productivity comparisons by using value and physical quantity information on the products obtained from industrial statistics of the two countries in question. The capital stock estimates needed for the total factor productivity indicator have been calculated from investment series by using the perpetual inventory method by assuming the same depreciation rate for each country. Investments of each country have been converted into dollars by using the purchasing power parities of the investment goods.

All in all, it can be argued that since Finland has joined the group of the productivity leaders whose role is to shift the international technology frontier, R&D efforts are today even more important for Finnish competitiveness and growth than in the past.

The new growth models suggest that there are externalities involved in the processes by which technologies are improved in the economy and due to which there is a danger of markets generating sub-optimal results. In other words, from a social standpoint market-generated private R&D efforts may remain too low. One important implication of the many new growth theories is that the welfare of a nation can be increased by technology and trade policies. R&D support is one of the most important tools available to governments.

According to R&D statistics, public funding of R&D in the Finnish business sector in 1997 amounted to some FIM 740 million, of which the National Technology Agency (Tekes) accounted for 80%. The aim of this sizeable public investment is to guarantee that the total R&D level in the economy is sufficiently high for enhancing long-term growth and competitiveness. To meet this end, however, public R&D should not crowd out privately financed R&D investments in a major scale. Available international evidence indicates, though, that direct financial support to R&D has typically only a modest, albeit positive, effect on total business R&D expenditure (OECD, 1998). Niininen (1997) has confirmed this finding using Finnish firm-level data.

Another requirement for the support to be beneficial to the economy is that R&D contributes to productivity growth. Especially from the point-of-view of the taxpayer, it is of interest to know how the public R&D support has affected productivity. Niininen (1997), for instance, found no evidence for a positive effect of publicly financed R&D on firm-level productivity growth. R&D activities of firms that are induced by support may also have indirect effects, however. Public R&D funding may increase the total R&D of an industry which may, in turn, have a positive impact on the productivity of all firms due to spillovers. For this reason it is important to also account for potential effects of industry-level R&D on firm-level productivity performance.

Economic theory provides several reasons why the skill level of the workforce can be expected to have a positive effect on future productivity growth. An important argument is that a high skill level in the appropriate fields may enable the workforce to develop, implement, and adopt new technologies.[3] To put it differently, highly educated personnel may not only be more efficient in producing output with available technology but will also be better in developing technologies, both of which contribute to productivity growth. Hence, when analysing the determinants of productivity growth, it is important to take workforce skills into account as well. First, as government invests a fair amount of money into education, it is important to know what the return is on this investment in terms of technological progress. In addition, R&D and skills are associated with each other. Indeed, a majority of the firms' R&D expenditures consists of wages and supplements of the high-skilled workforce. On the other hand, skilled labour may be important also for firms having little or no R&D activities, since it may

[3] See Nelson and Phelps (1966); Welch (1970); Romer (1990) and Benhabib and Spiegel (1994). For empirical results, see Leiponen (1995) and Ilmakunnas et al. (1999).

help to absorb spillovers.[4] Finally, a high skill level may be needed in order to achieve R&D efforts that are effective in terms of productivity.

Globalisation of R&D has been one of the central tendencies in recent decades. Multinational enterprises (MNEs) typically locate their R&D activities in several countries and transfer technological knowledge across borders. MNEs may support their subsidiaries technologically, which contributes to productivity. Foreign ownership may also bring valuable knowledge or pressure to the firm, leading to improvements in technology exploitation and generation. In other words, the relationship between productivity and R&D efforts may be different between foreign- and domestic-owned firms (see Pajarinen, 1999). Also this aspect should be taken explicitly into account when analysing determinants of productivity growth.

Small and medium-sized firms (SMEs) are often seen as engines of growth. They are claimed to be innovative and thus to play a crucial role in advancing technology and increasing productivity. Pakes and Ericson (1998) develop a model that seeks to explain the evolution of new firms. A central feature of their model is that firms have an active role in learning how to use inputs in an efficient way.[5] In order to maximise their profits, firms may try to speed up their learning process by investing in R&D. However, firms have to come to a decision without knowing for certain what effect the investment is going to have on their productivity performance. The firms maximise the net present value of their expected cash flows. Ex post some firms may appear to have performed poorly and some well with their R&D efforts. As new firms are typically small, this model provides a framework for considering technological progress among SMEs. One common lesson of this model as well as from some other models on the life-cycle of the firm (see for example Jovanovic, 1982, and Cabral, 1995) is that there is large variance in performance among SMEs. In this study we try to recognise those observable factors that stand out as important for SMEs. We study in particular whether the role of a firm's own R&D efforts and industry-level R&D for productivity growth varies between large firms and SMEs.

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4 For Finnish evidence and discussion on the role of skills, see Leiponen (2000a, 2000b).

5 Jovanovic (1982) developed a life-cycle model based on so-called passive learning. Entering firms are heterogeneous with respect to their unit costs, which are not directly observable. A firm learns about its relative position only gradually after production has started.

The rest of this chapter is organised as follows. In Section 2 we introduce our econometric framework and estimation models. Data and variables are described briefly in Section 3. In Section 4 we report and interpret the estimation results and also investigate whether there are differences in the productivity relationships between firms of different size. Section 5 concludes the study.

2 Econometric framework

We use two different approaches in our empirical analysis. In the majority of studies in this field it is assumed that the Cobb-Douglas production function provides a sufficiently close approximation of the production technology.[6] The function may be expressed as:

(1) $$\ln(Y_{it}) = \delta + \alpha \ln(K_{it}) + \beta \ln(L_{it}) + \gamma \ln(C_{it}) + \lambda t + \varepsilon_{it}\,, \qquad i = 1,\ldots,N \quad t = 1,\ldots,T,$$

where N stands for the number of firms and T for the number of years covered. Y is a measure of output (in this study value added deflated with the implicit price index of production obtained from the National Accounts at the 2-digit industry level), L is labour input (here measured by the number of employees in the firm) and t denotes the time trend. K measures the stock of physical capital that has been cumulated through investments made in the past and C captures cumulated R&D expenditure. The R&D stock is usually approximated by a weighted sum of current and past R&D expenditure. The unknown parameters α, β and γ can be interpreted as the output elasticity of physical capital, labour and R&D, respectively. The estimate of parameter λ indicates the trend of the disembodied technological progress. The error term ε reflects measurement errors in the variables as well as any errors in the model specification which arise because firms have different production functions. All models in this study are estimated by the OLS technique.

An important component of this residual term is likely to be due to heterogeneity in terms of the quality of the production techniques in use in the different enterprises. In addition, the error term captures differences in the quality of output. In order to examine productivity differences in a strict meaning we need to assume that possible cross-

6 See Mairesse and Sassenou (1991) who provide a good review of the methodology and empirical findings of studies on productivity and R&D effort using firm-level data.

sectional differences in price levels reflect solely variations in product quality between producers. The error term, however, may to a large part also comprise more or less permanent and profound firm-specific effects, and as these effects can be expected to correlate with the input decisions, we may run into some potential estimation problems. To give an example, let us assume that a particular firm has a particularly skilled manager, which is manifested as a large positive residual in the statistical model. This sort of firm may find it possible and profitable to have large R&D expenditures. In other words, we may encounter an omitted-variable bias in our coefficient estimates. A common way to escape this problem is to take the fixed firm effect out by using short or long differences in the estimations (see Hsiao, 1986; Griliches and Regev, 1995).[7]

There are problems involved also in measuring the R&D stock *C*. These considerations lead us to an alternative empirical model that is frequently used in the literature of R&D and productivity. In this formulation the levels are replaced by growth rates. Additionally we include the lagged level of productivity in the initial year, *ln(Y/L)*, from which productivity growth is calculated. This variable controls for differences in the starting level of productivity growth. Firms with a low initial productivity level may be able to achieve superior productivity growth because of the so-called catching-up potential that is gained from adopting knowledge and technology from firms of superior productivity and technology levels. If the initial productivity level is high, an extra effort might be needed to retain a high productivity growth rate.[8] At this point we re-write the equation into an intensive form so that the deviation from constant returns is measured explicitly (the subscripts *i* and *t* are dropped here for convenience):

(2) $$\Delta \ln(Y/L) = \lambda + \psi \ln(Y/L) + \alpha \cdot \Delta \ln(K/L) + (1-\alpha-\beta)\Delta \ln(L) + \rho(R/Q) + X\theta + \mu\,,$$

7 In this setting we need not assume that the price differences between firms reflect quality differences of their products. All we need is that the differences in the price changes among firms reflect differences in quality changes. In other words, price margins need not be zero; constant margins will do for our purposes.

8 The importance of including the initial level of productivity in the model has been emphasised for example by Benhabib and Spiegel (1994) in the context of analysing the role of human capital for the growth of output. Similar considerations apply here as we are studying the impact of intangible assets created by the firm's R&D efforts on output growth.

where R denotes the firm's annual expenditure on R&D, ideally, net of depreciation of the previously accumulated R&D stock, Q is the sales of the firm[9], and Δ is the difference operator.

The parameter ρ is of special interest here. In this study and in many others the firm's R&D expenditures, R, are measured in gross terms, i.e. the depreciation in the cumulated R&D stock is not taken into account (or is assumed to be zero). This being the case, the parameter ρ is conventionally interpreted as the *gross* rate of return. There is also a problem of double-counting in R&D expenditures with respect to labour, capital and value added as pointed out by Schankerman (1981).[10] In this study we have not done so-called double-counting corrections. This has certain implications for the interpretation of the estimates of ρ. When ignoring the double-counting problem we should not expect large positive estimates for ρ unless the returns on R&D investments are particularly high, that is, if there are excess rates of return to R&D expenditures. However, as we are examining determinants of productivity *growth,* the double-counting correction does not seem to be as compelling as when estimating productivity levels.

Hall and Mairesse (1995) found only a small difference in the estimates for the gross and net R&D coefficients; a result that they, by the way, saw as rather puzzling. When they adjusted the data for double-counting the net rate of return to R&D rose by about 3 to 4 percentage points. Thus we have reason to believe that our estimates of ρ may give a slightly downward biased view on the gross and net rates of return to R&D investment in Finnish firms. But we are, on the other hand, more interested in the differences between different funding sources and between different sectors than in the actual return to R&D investment which, moreover, is extremely difficult to measure reliably. We have also added a vector of certain other variables, X, in order both to analyse some additional factors of interest and to control for given characteristics of heterogeneous firms.

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9 Usually R&D intensity is measured by using the same output concept as used in the productivity measure (see Mairesse and Sassenou, 1991). As we do not include material inputs in the model it is natural to use the value added concept where intermediate inputs are netted out. R&D intensity is measured here by using information in the R&D survey data where value added is not available. See also footnote 17.

10 This means, for example, that the number of the R&D personnel is included in L and their wages and supplements are included in R. When double correction has been implemented the R&D personnel is not included in L.

The approach outlined above assumes a specific (Cobb-Douglas) formulation of the production technique and requires estimation of parameters α and β, for example. Due to endogeneity of explanatory variables and errors-in-variable problems, however, the regression estimates may fail to correspond to the true causal relationship. If we assume competitive input markets, the need for estimating the output elasticity of labour and capital input can be avoided. In that case, α and β can be measured by the corresponding cost shares (see for example Chambers, 1988). Moreover, if we assume perfectly competitive product markets, where there are no pure profits, the cost share equals the income share. We also assume that there are constant returns to scale. Albeit some simplifying assumptions are needed, this index approach has some appeal as it allows us to make use of readily available information on costs or incomes in order to estimate output elasticities of inputs.

Under the conditions described above, β is labour compensation (wages plus social security payments) divided by value added, and $\alpha = 1-\beta$. In this study we use input shares of respective 2-digit industry for the period in question, which are obtained from the National Accounts.[11] We have calculated a total factor productivity indicator (*TFP*) which is a factor-share weighted geometric average of labour and capital productivity. This leads us to the following specification:

(3) $$\Delta \ln(TFP) = \lambda + \psi \ln(TFP) + \rho(R/Q) + X\theta + \mu \, .$$

3 Data and variables

Here we introduce briefly the main variables that are included in the estimated statistical models. The data set used in explaining productivity growth is described in the data appendix (Appendix 1 of this chapter). Some descriptive statistics of the variables are also provided by Lehtoranta in Chapter 2 of this volume.

The firm's total R&D expenditure (*R*) is divided into two distinct main components: privately financed R&D (*RP*)[12] and publicly funded R&D (*RG*). Furthermore, we have divided the publicly funded R&D

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[11] To be more specific, we use average shares in the periods in question.

[12] This item includes the firm's own funds and loans used for R&D expenditures and funds obtained from other private-sector organisations.

component into two sub-items; subsidies and loans from Tekes (*RGTE*), and from other public sources (*RGOT*).[13] Attempts are made to capture possible differences in the return to R&D expenditure across sectors by creating interaction terms, that is, by interacting the R&D variables with three sector dummy variables (*MANU* for manufacturing, *SERV* for firms with their main activities in the service industries, and *CME* for construction, mining and electricity). For the purpose of analysing the impact of R&D spillovers we employ a variable (*RDINT*) that measures R&D expenditures per output at the industry level (R&D intensities of the industries are shown in Appendix 2 of this chapter). The dummy variable *FOROWN* denotes a firm where the share of foreign ownership is at least 50%.[14] The dummy *IPROS* indicates if the firm has made innovative efforts concerning production processes in the recent few years and *IPROD* measures the corresponding spread concerning product innovations. These variables are obtained from innovation surveys that have been carried out for a sample of firms in 1991 and 1996. Consequently, the number of observations in the regression analysis is substantially reduced when these innovation dummies are added to the model.

We also use variables that control for the education of the employees in the enterprise. *SKILLT* indicates the share of the staff with a higher education in the field of engineering or natural sciences and *SKILLO* the share with a higher education in some other field (like in (business) economics). Finally, two dummy variables identify the size of the firm. Size is defined by taking the average number of employees in the beginning and at the end of the period under consideration.[15]

Data on output, employment and capital needed for the measurement of productivity cover the period from 1986 to 1996. We analyse

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13 A public loan obtained for R&D expenditures differs from a private loan in that one does not need to re-pay the public loan if the project proves to be a failure.

14 We have also experimented with 20% as the criteria for foreign ownership in the regression models, without much effect on the parameter estimates, however.

15 By this we try to avoid the bias that may arise if measuring the number of employees either in the beginning or at the end of the period only. If the number of employees in a firm is erroneously too small in the beginning of the period because of measurement error, we would expect the growth of labour input during the period to be overrated, and consequently productivity growth would be underrated. As a result, we would expect the productivity growth performance of small firms to seem falsely weak if the firms are classified into size groups according to the size at the beginning of the period. On the other hand, a too rosy view of the productivity progress of small firms would be given if the classification was done according to the size at the end of the period.

the determinants of productivity growth by using both two-year differences (short differences) and four-year differences (longer differences). In the former case calculations are done over the periods 1986–88, 1988–90, 1990–92, 1992–94 and 1994–96, and for the longer differences over the periods 1988–92 and 1992–96. The periods are pooled in the estimations, but period dummies are added to control for the productivity growth in the different periods.

Hall and Mairesse (1995) bring up another problem that is present when one applies the productivity growth approach, i.e. uses model (2) or model (3). Namely, it is not entirely obvious what the relevant timing for the R&D variable is. They also point out that a bias may arise if the firm's R&D expenditure is divided by contemporaneous output because in that case an error in output would affect both the dependent and the explanatory variable. In our estimations of short differences we have measured the R&D intensity in the following way. We make use of the information available in the R&D survey, which has been carried out bi-annually. Our data on R&D expenditures include every second year from 1985 to 1995. When measuring productivity growth from year *t*–2 to year *t* we use the average non-missing R&D intensity in the years *t*–3 and *t*–1.[16] When examining longer productivity differences from *t*–4 to *t*, we have defined the R&D intensity variable as an average of the years *t*–5, *t*–3 and *t*–1.[17] Also our education variables defined in levels

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16 It may be argued that R&D intensity affects productivity after some time lag and that recent investments in R&D may therefore be irrelevant in terms of current productivity. To allow for this possibility we have also estimated models with R&D intensity measured for the year *t*–3, without qualitative changes in the results. The number of observations, however, drops substantially when the R&D intensity is measured at one point of time only. The reason for this is that the R&D survey does not include all small firms, only a sample of them. As the sample changes from survey to survey, the probability to include a particular small firm in our analysis sample is, of course, substantially higher when the R&D intensity of that firm is measured by taking an average of non-missing values of R&D intensity from more than one year.

17 As a denominator we have used sales as reported in the R&D survey. In other words, we have taken both rows of the ratio measure from the same source. This may be an important aspect as the delineation of the firm-unit may in some occasions be different in the R&D survey and the Financial Statements survey. This is because sometimes firms may find it difficult or impossible to distinguish R&D expenditures of the legal unit from R&D expenditures of the same enterprise group. In that case they are allowed to report R&D expenditures of the enterprise group and the corresponding sales and other variables. In these cases the other legal units of the same enterprise group are dropped from the sample. As we have defined the R&D intensity variable in this way we do not have reason to believe that errors in the crucial explanatory variables are correlated with those of the dependent variable, and thus with the error term

are specified according to the same principle.[18] The dummy variables for ownership, in turn, reflect a single point in time (t–1).

The results reported in the next section are obtained from estimations also including firms that have announced that they have had no R&D expenditures whatsoever, i.e. firms with an R&D intensity equal to zero. We have also estimated the models for firms with the zero intensity ones excluded. This decreases the number of observations substantially, for example in model (1) from 4,760 to some 2,500 firms (Table A1 in Appendix 3 of this chapter). No qualitatively important changes, however, occurred in the estimated coefficients after restricting our sample to R&D investing firms. All in all, we have included all those observations that have non-missing values for each and every variable used in the estimated model specifications.

4 Empirical results

In this section we report findings obtained by estimating equation (2) and equation (3) from two- and four-year differences.[19] In other words,

μ. As pointed out above, this might have been the case if we had used Y_t or $Y_{t\text{-}2}$ ($Y_{t\text{-}4}$ in longer differences) from Financial Statements data as a denominator.

18 For example, the education variable *SKILLT* for explaining productivity growth from t–2 to t is calculated by averaging respective (non-missing) shares in the years t–2, t–1 and t.

19 Although the output elasticity of inputs and the deviation from constant returns are not of primary interest here, the estimates obtained from the labour productivity growth models are worth some brief comments. The coefficient of *dln(K/L)* (the difference of log capital intensity) should indicate the magnitude of the output elasticity of physical capital. The estimates, however, are well below the reasonable range. The income and cost shares suggest that a proper value should typically lie somewhere between 0.3 and 0.5 depending on the industry and year in question. Hence, the role of increasing tangible capital intensity for labour productivity growth is underrated when using the production function approach. The errors-in-variable problem offers one obvious explanation for our apparently downward biased estimates of capital intensity. Given the (quasi-)fixed nature of capital input and the practical problems involved in measuring it, it is reasonable to believe that the dispersion in the changes of capital intensity in our data signals poorly the true changes especially over a relatively short time period. There is, however, another estimation problem that works in the opposite direction; there may be a spurious relationship between labour productivity growth and capital intensity growth as the firms' investment decisions may partly reflect an anticipated improvement in future labour productivity. The estimates of *dln(L)* seem to suggest that diminishing returns to scale are prevailing. This result is subject to some suspect, too. If the change in

we use both labour and total factor productivity as the dependent variable, and base the estimations on both short and longer differences. Models for labour and total factor productivity growth estimated with short differences are shown in Appendix 3 of this chapter. In every model we have included controls for, respectively, past labour and total factor productivity levels.[20] In all cases past productivity has a significant negative coefficient, which points to the presence of a "regression-toward-mean" phenomenon (e.g. Friedman, 1992). Thus we should not interpret this result solely as an indication of convergence of productivity levels among firms.

4.1 Privately and publicly funded R&D effort

We obtain no empirical evidence in support of the view that the firm's R&D intensity (R/Q) has an extra[21] positive effect on productivity growth when using a pooled data set spanning from 1988 to 1996.[22] This finding holds irrespective of whether the dependent variable is labour productivity or total factor productivity growth. Analysing with short and longer differences leads to the same conclusion. Moreover, it seems that the manufacturing sector does not differ from the service sector in this respect, an aspect examined using interacted terms.[23]

However, when the analysis is performed separately for each period, R&D turns out to be negatively and significantly associated with productivity growth in the period 1994–96. When this period is dropped from the pooled data, the estimations generally yield positive estimates for R&D intensity, which are often statistically significant as

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labour input is measured with error, the same error affects the dependent variable and, consequently, it is conveyed into the residual term. We would therefore expect the coefficient of the labour variable, which indicates a deviation from constant returns to scale, to be downward biased.

20 Besides the variables shown in the table, in all models we have also controlled for sector group, size and time period.

21 As mentioned above we have not carried out the so-called double-counting correction, and therefore the coefficient of the R&D intensity variable measures the excess private rate of return on R&D rather than the total private rate of return. In other words, a zero value of the R&D intensity coefficient does not suggest that R&D investments have been unprofitable but that those particular investments have not been excessively profitable (see Mairesse and Hall, 1995).

22 In several of the model specifications the statistical significance is low because of large standard errors.

23 See Models (5) and (17) in Appendix 3 of this chapter.

well (results are reported in Tables A4 and A5 in Appendix 3 of this chapter). It is not self-evident why this last period in our analysis is so exceptional. On the other hand, the Finnish economy was recovering from a severe recession in these years, and productivity growth was exceptionally rapid on average. It is possible that this extreme growth performance of firms was dominated by the improvement of utilisation of existing resources.

Broadly speaking, the model specifications where the firm's R&D intensity is split into a privately financed and publicly financed component suggest that there are no clear-cut productivity-inducing differences depending on the source of funding. We have also examined whether there are differences between different public sources. No evidence can be found for this; that is, the support given by Tekes is neither more nor less effective from a productivity point-of-view than the support firms obtain from other public sources.[24] There is, however, one exception to this general outcome. When the skill level of the personnel is controlled for, the firm's R&D intensity in general and the privately funded component in particular turns significantly negative, whereas the publicly funded component appears to remain statistically insignificant. The impact of skills on productivity will be discussed in greater detail below.

4.2 Industry-level R&D intensity

For the purpose of evaluating the impact of R&D spillovers within industries, we have included an industry-level R&D intensity variable in most model specifications estimated here. Generally, we obtain a fair amount of evidence showing that industry-level R&D intensity has an important impact on the productivity growth performance of firms. This variable obtains a large statistically significant coefficient estimate in practically all models estimated for this study. The coefficient is positive, albeit only weakly significant ($p = 0.13$), also in the case where fixed industry effects are controlled for (using industry dummies).

All in all, our results suggest that industry-level spillovers are important for firms. This finding gives at least some support to the view that there is a role for technology policies, given that the firms' total R&D effort can be increased by means of the policy instruments available to the government.

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24 See Models (3), (4), (15) and (16) in Appendix 3 of this chapter.

4.3 Skills

The role of education for productivity growth is examined by including two variables, *SKILLT* and *SKILLO*, which measure firm-specific skill levels. The estimates of the two skill-level variables display significant positive effects on productivity growth. This finding is in accordance with the results obtained by Leiponen (1995) and Ilmakunnas et al. (1999), and suggests that education increases the steady-state productivity growth rate by enabling the workforce to create, adopt and implement continuously new technologies.

If we consider schooling as a distinct input in the production function we would expect that it is the change in the educational level rather than the level of education that should enter our model explaining productivity growth (see the discussion and literature review in Benhabib and Spiegel, 1994, as well as Krueger and Lindahl, 1999). Indeed, we find some confirmation for the growth in the share of higher educated employees being positively associated with productivity growth, as one would also expect. But this result seems to hold only for an education in other fields than natural sciences and engineering (see also Leiponen, 1995).[25]

We also allow the coefficients to vary across sectors (see Model (8) and Model (20) in Appendix 3 of this chapter). Interestingly, there seem to be notable differences between sectors in the role of skills by field of education. Moreover, the sectors differ from each other more or less in a way that one might intuitively expect. We can conclude from the results that in manufacturing skills related to natural sciences and engineering are important for productivity growth whereas skills in other fields are not essential. In the service sector, in turn, the results are somewhat different. According to the results obtained from the labour productivity growth specification (Model (8)) it is the skill level in other fields than natural sciences and engineering embodied in the labour input that is important for creating, adopting and implementing the knowledge that is valuable in terms of productivity for firms engaged in service output. On the other hand, Model (20), in which total factor productivity growth is the dependent variable, suggests that "technical" skills are important for service output whereas other skills are not. All in all, we gain unambiguous evidence that "technical" skills are important for productivity growth in manufacturing, but only weak signs for them being useful in services. Other skills, in turn, do not

[25] See Models (7) and (19) in Appendix 3 of this chapter.

seem to be effective in manufacturing, but possibly have some relevance in services.

The *increase* in "technical" skills (*DSKILLT*) appears to have a negative effect on productivity growth in manufacturing and services. One obvious candidate when trying to explain this result is that the increase in the number of engineers and scientists may be linked to the start-up of projects that aim to increase output in the longer term. If the increase in such employment is not reflected in output in the short term, the firm may appear to perform poorly in terms of short-run productivity growth. In view of our findings concerning the role of skill levels as discussed above, the firm may be expected to perform better in the long run. We obtain for both sectors some scant evidence that an increase in other skills has a more immediate non-negative effect on productivity growth than "technical" skills.[26]

The inclusion of variables controlling for the level and change of skills in the firm has some important consequences for other coefficient estimates in the models. The estimate of the *R/Q* variable becomes significantly negative after conditioning on skills.[27] Obviously a high education level is related to the R&D efforts of a firm. This being the case, it is possible that our variables that control for the skill level of the staff pick up a substantial proportion of the full impact of innovation efforts on productivity growth.

Alternatively, R&D expenditures may be an incomplete and inaccurate measure of the actual innovation effort of the firm. Conditional on the other factors that are held constant in our models (especially the educational level) it is possible that the firm R&D intensity variable in our data conveys a deficient or distorted signal of true and pure long-term productivity effects of R&D efforts. It turns out that, for some reason, it is the privately funded component of the firm's R&D that becomes negatively associated with productivity growth, whereas the coefficient estimate of the publicly financed component seems to be robust to the inclusion of skill controls. This can be seen when comparing the coefficient estimates of *RP/Q* and *RG/Q* in Model (3) with Model (8) and in Model (15) with Model (20).

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26 See the coefficient estimates of the *DSKILLO*MANU* and *DSKILLT*SERV* variables in Models (8) and (20).

27 When the period 1994–96 is excluded from the analysis, the coefficient estimate is close to zero in these specifications.

The approach applied here, based on an augmented Cobb-Douglas production function specification, assumes that inputs are substitutes to each other. It is possible, however, that this is not the case especially when it comes to skills and R&D intensity. If these inputs are in fact complements, which seems to be a reasonable assumption, the inclusion of the skill variables may result in a downward bias in the estimates of the return to R&D. One can nonetheless conclude that augmenting research capital is not in itself sufficient to increase the firm's productivity; it has to be accompanied by an increase in labour skills (see Mairesse and Sassenou, 1991). To explore this possibility we have interacted R&D intensity and skill variables. Unfortunately, the results of these experiments (not reported here) appeared to be rather shaky depending on the choice of specification and sector coverage.

Estimations using four-year instead of two-year periods do not bring about qualitatively significant changes in the results and interpretations concerning the role of skills in the process of productivity progress in firms (results not reported here).

4.4 Foreign ownership

Models (9) and (21) include a dummy variable that denotes foreign ownership.[28] The estimated coefficient in the labour productivity growth model suggests that productivity growth is somewhat faster among foreign-owned firms as compared to domestic-owned firms, conditional on the other factors that are held constant in the model. The inclusion of the initial productivity level turns out to be crucial at this point. If dropped, the coefficient estimate of the foreign-ownership dummy becomes close to zero and turns statistically insignificant. Model (21) explaining total factor productivity growth does not indicate any difference in productivity growth performance between domestic- and foreign-owned firms.

In Models (9) and (21) we have also examined whether there is a difference in the return to R&D effort between foreign- and domestic-owned firms. The standard errors of the estimates are too large to allow us to draw any conclusions in this respect.

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[28] This information is available since 1989 and therefore we are able to include only the last three periods, i.e. 1990–92, 1992–94 and 1994–96. Our variable for foreign ownership is imperfect in the sense that possible indirect links of ownership are not taken into account.

4.5 Innovations

We have investigated whether product or process innovations made in the past few years show up as positive factors of productivity growth. As the innovation survey has been carried out only twice, in 1991 and 1996, and as the survey has covered only a sample of firms, the number of observations drops considerably when accounting for these aspects. For the purpose of evaluating the overall effect of restricting our sample to cover only those firms that have responded to the innovation survey, we have first re-estimated Models (2) and (14) with the smaller sample (Models (10) and (22)). There are some changes in the results due to the reduction in sample size. In particular, the *R/Q* variable now takes on a large negative and statistically significant coefficient estimate. In other words, in this particular sub-sample the relationship is different from that in the larger sample used in the previous analyses. Thus, we seem to have some sort of sample selection problem in hand that should be kept in mind when interpreting the results obtained from Models (11), (12), (23) and (24). By comparing Model (10) (Model (22)) with Model (11) (Model (23)) we see that the inclusion of the innovation variables does not *per se* seem to alter the coefficient of the *R/Q* variable very much.

Model (11) suggests that product innovation efforts have a positive impact on productivity growth, as one would expect. Model (23) also shows a positive coefficient estimate for product innovations, but it is statistically insignificant. The absolute value of the coefficient for the process innovation dummy in Model (11) is of the same order of magnitude as that for product innovations but of the opposite sign. Thus somewhat surprisingly, process innovations seem to be negatively related with productivity growth over the next few years. When we drop the dummy that controls for process innovations, the coefficient estimate of the product innovation dummy is still positive but statistically insignificant (results not reported here). If we drop the product innovation dummy instead, the coefficient estimate for the process innovation dummy is still negative and statistically significant (results not reported either).

One potential explanation for these findings might be that the time period needed before process innovations come into light in the form of increased output per input is longer than for product innovations. The implementation of a process innovation may require substantial investments in tangible capital which may turn into efficient use only after a long period (see Doms, 1992). On the other hand, one could also argue that this should be the other way round, i.e. product innovations require a longer period to implement because of marketing needs, for example. We have examined this matter by regressing productivity growth in the period from 1994 to 1996 on process (and product) innovations performed at the turn of the decade 1980/90 (results not reported here). The coefficient of process innovation moves close to zero and becomes statistically insignificant. In this setting, the coefficient for product innovations is basically the same as in Model (11), but now statistically insignificant.[29] Finally, in Models (12) and (24) we allow for different estimates for the *IPROS* and *IPROD* variables by sector, and we also include skill variables. Statistically significant estimates are obtained for the manufacturing sector only. The problem is that there are quite few firms left in the other sectors in this restricted sample of ours.

4.6 Size, R&D and productivity

In this sub-section we examine how firms differ according to size as far as the impact of R&D, innovation and skills on productivity are concerned. The firms are classified into three groups; small firms employing less than 50 persons, medium-sized firms employing at least 50 but less than 250 persons, and large firms with at least 250 persons employed.[30] We make use of size dummies to create various interaction terms in order to investigate whether there are differences in these relationships between firms of different size. At this point, we examine manufacturing firms separately from firms engaged in other sectors. We have estimated the same models for service sector firms, but due to insufficient degrees of freedom we were unable to obtain statistically meaningful models with size interactions included. We have used labour productivity as well as total factor productivity growth as the dependent variable. The results are shown in Table A3 in Appendix 3 of this chapter (Models (25) – (30)).

Firstly, it turns out that the relationship between firm R&D intensity and productivity growth is negative especially among medium-sized

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[29] There were 254 observations available for this analysis.

[30] It should be kept in mind that the size of the firm is measured here by taking the average of the number of employees in year *t* and *t*–2.

firms.[31] The coefficient of R&D intensity is generally negative also for small and large firms but is usually statistically insignificant.

Secondly, we obtain some empirical evidence that industry-level R&D intensity is unimportant (or at least less important) for the productivity performance of large firms, in contrast to small and medium-sized firms where the impact seems to be substantial.[32] The difference by size in this respect is less outstanding in those models where total factor productivity growth is the dependent variable. It is possible that large firms tend to have activities in various industries and thus the R&D spillovers in its main industry are not that decisive.

The estimated models further suggest that productivity growth is slower among small firms than among larger firms when various factors are controlled for. However, this result is sensitive to the inclusion of the past productivity level. If that variable is dropped from the model the coefficient estimates of the *SMALL* and *MEDIUM* variables become statistically insignificant.

Just as before, firm R&D expenditures per sales become (more) negatively related with productivity growth after conditioning on skill variables. This appears to be the case especially for medium-sized firms. We obtain fragile indication that among both medium-sized and large firms also a high level of "technical" skills is more important than among small firms. However, this result should be read cautiously because of the multicollinearity problem that seems to be present here.

To conclude this sub-section, we take the final element into consideration; that is, whether the firm has put product or process innovations into practise in the past few years. Like earlier, our sample becomes substantially smaller. However, qualitatively the results are by and large in accordance with the findings reported above. Again we find that process innovations are negatively, and product innovations positively related with productivity growth, albeit a proper statistical significance level is obtained for medium-sized firms only (see Models (27) and (30) in Appendix 3 of this chapter).

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31 See coefficient estimates of the *R/Q*SMALL*, *R/Q*MEDIUM*, and *R/Q*LARGE* variables in Models (25) – (30) in Appendix 3 of this chapter.

32 See coefficient estimates of the *RDINT*SMALL*, *RDINT*MEDIUM*, and *RDINT*LARGE* variables in Models (25) – (30) in Appendix 3 of this chapter.

5 Conclusions and concluding remarks

This study has focused on disentangling the impact of R&D intensity as well as of some other related key factors on productivity growth performance of Finnish firms engaged in manufacturing and in selected service sectors. The analysis has been made by using both labour productivity growth and total factor productivity growth as the dependent variable. The data set and the analysis span from the year 1986 to 1996.

We do not find evidence on extra returns to firm's R&D investments, i.e. according to the estimates returns to R&D do not seem to be in excess of the normal rate of return to physical capital. We have problems with large standard errors, which prevent us from obtaining statistically significant coefficient estimates. We have also tested whether there are differences in returns by the source of funding. We find no clear indication of such differences. A somewhat puzzling observation is that the independent effect of R&D intensity on productivity growth seems to be clearly negative in the period from 1994 to 1996. When only earlier periods are examined with a pooled data set, we obtain some, albeit fragile, evidence of a positive contribution of R&D intensity.

Industry-level R&D intensity, in contrast, proves to be an important contributor to productivity growth. This result suggests that industry-specific knowledge, valuable in terms of productivity, spills over to firms.

The role of skills for technological progress as well as for implementation and utilisation of technology stands out strongly in our results. Highly skilled labour turns out to be of crucial importance for the firm's productivity growth. Especially the proportion of employment with a higher education in engineering and natural sciences seems to be valuable in terms of productivity growth in manufacturing and apparently also in services. The share in employment with higher education in other than "technical" fields, in turn, appears to be important mainly in services. In contrast to these "level" results, an increase in the share of "technically" high-skilled labour is not reflected in productivity in the short term. In fact, for manufacturing such an increase comes out with a negative impact on productivity growth. This result may originate from the fact that developing technology is usually a long-term process. A large proportion of the "technically" skilled labour develops products and processes for the future, and in this sense contributes only marginally to current output. Increasing their share in the workforce may in the short run negatively affect productivity, as measured by output per total employment.

However, skilled labour is valuable not only in developing new and better technologies but may have a critical role to play also in the utilisation of the existing technology. Skilled persons are able to extract production potentials efficiently and are thus more productive than their less-skilled colleagues. We have reasons to believe that it is easier and faster to improve productivity through improving efficiency than through technical progress. We might expect that increasing the share of skilled labour will improve productivity through a more efficient utilisation of the existing production capacity. Our regression results are at least partly in keeping with this notion, but only as far as skills in other fields than engineering and natural sciences are concerned. According to the estimation results obtained here, an increase in the share of "non-technically" skilled labour is positively related with productivity growth. This seems to hold for services and weakly also for manufacturing. In other words, our results are in agreement with the notion that "non-technical" skills are useful for the utilisation of productivity potentials.

We gain some evidence that foreign-owned firms are able to achieve faster productivity growth than domestic-owned ones. We do not, however, observe statistically significant differences in the return to R&D between foreign- and domestic-owned firms.

We have studied the impact of product and process innovations on productivity growth as well. Interestingly, process innovations made in the past few years seem to be negatively correlated with productivity growth whereas for product innovations the impact appears to be clearly positive.

Finally, we have investigated whether there are differences between manufacturing firms according to size. The return to R&D seems to be clearly negative for medium-sized firms only. We also obtain some indication that industry-level R&D intensity is especially important for productivity growth among small (and possibly among medium-sized) firms.

This study, just as the study by Niininen (1997), which uses a different approach and method and is based on a partly different data set, thus provides a somewhat mixed view on the potentials of public R&D support for enhancing productivity. Neither one of the studies find any evidence that public R&D support leads to improved productivity of the firm. However, the results obtained by Niininen (1997) indicate that total R&D investments can be promoted by tools available to the government. Direct subsidies appear to have a larger effect in this respect than subsidised loans. All in all, the analysis of Niininen (1997) suggests that the total R&D stock of the industry or economy can be increased by actions of government. The importance of this finding is strengthened by the results obtained here since the total R&D efforts within an industry have been shown to have a positive effect on the productivity of firms. These industry-specific spillovers are found to be especially important for small firms.

This study further demonstrates that investments in education are likely to give rise to substantial returns in terms of accelerated technological progress in the future. It seems that at least up till now education in "technical" fields has been valuable for productivity growth in manufacturing. (Leiponen (1995) draws the same conclusions based on a different data set.)

The failure to demonstrate a significant link between R&D and productivity may spring up from the fact that the process of technological progress is extremely complex. There is obviously a multitude of factors other than R&D affecting productivity simultaneously and they may largely dominate the signal in our data set. We use a relatively large sample of firms, which is a pre-requisite for investigating and comparing determinants of technological progress across different subgroups of firms, especially small versus large firms. On the other hand, the quality of the data may vary with the type of firm. The task of controlling data quality is extremely laborious. Nevertheless it would be worth an effort, the return of which in terms of quality of econometric results is likely to be substantial. Despite the failure with respect to R&D, however, it is important to emphasise that many clear links between productivity and other factors have been confirmed in our study. This is quite encouraging as it gives us reasons to believe that our data contain high quality signals in at least some crucial respects.

Our analysis can be extended in various directions in future work. In this study we use the firm as the observation unit. The analysis could be repeated by using plant-level data that are readily available for manufacturing. Industrial statistics data for Finnish manufacturing cover the period from 1975 to 1998. The data include a wide variety of variables valuable in the analysis of productivity; for example, a capital input measure constructed by the perpetual inventory method. As regards the service sector, the potentials involved in the Business Register on plants for productivity analyses should be explored. In addition, this analysis could be extended by using more sophisticated methods for dealing with the question of endogeneity of explanatory factors. Finally, it might be useful to construct R&D stock measures for the purpose of a more comprehensive analysis, despite the difficulties one will encounter in that kind of work. There have been lots of changes in the ownership and also organisational re-arrangements in the Finnish economy in recent decades. This makes it difficult to create proper longitudinal linkages needed for constructing a measure of cumulative R&D effort from firm-level R&D data. In previous experiments with Finnish data undertaken by Husso (1997), this approach resulted in a considerable drop in the number of observations. Maybe careful treatment of enterprise demography by use of plant-level data, for example, would pay itself back in the form of a larger and more representative sample of firms.

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Appendices of Chapter 3

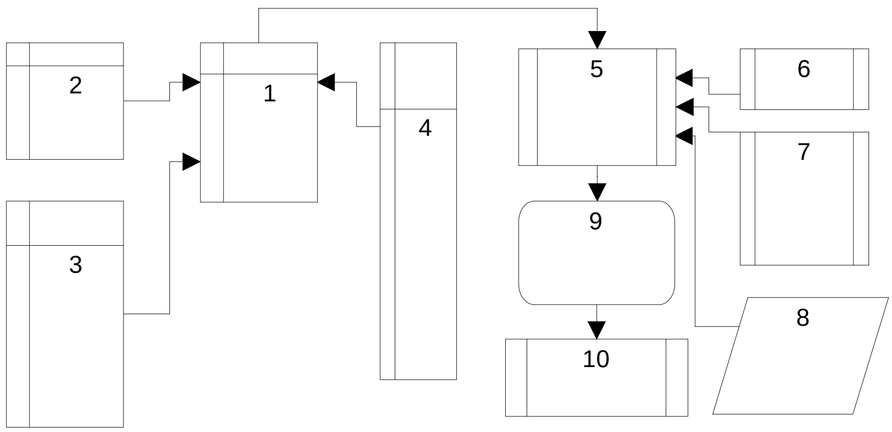
Appendix 1. Linking data sources for the analysis

The data set used in the analysis has been constructed from several distinct sources. These are:

I. Research and Development Survey
II. Financial Statements Statistics
III. Business Register
IV. Business Taxation Register data; Data on firms subject to the VAT settlement collected for taxation purposes.
V. Innovation Survey
VI. Register-based Employment Statistics
VII. ANBERD database on R&D expenditures by industries, OECD (extended to include service sectors by using national R&D statistics)

The process of linking separate data sources for our analysis is material because it determines the sample(s) that is used in the analysis. The accompanying graph illustrates the process.

Process used for linking data sources:



The firms that have responded to the *R&D survey* (data 1 in the graph) at least once during the period from 1985 to 1995 constitute the starting point for our sample of firms; the analysis covers only firms with non-missing values in the R&D survey. Another necessary condition for the inclusion of a firm in our sample is that it exists in the *Business Register* (data 4). Information on the industry and the share of foreign ownership is linked from this source. Figures on output, employment and tangible capital are obtained primarily from *Financial Statements Statistics* (data 2), which is a sample of firms that generally covers all large firms and a random sample of smaller firms. Earlier this sample was, in principle, the starting point for the R&D survey, too. In later years, however, the R&D survey has covered also some small firms that were not included in the sample of Financial Statements Statistics. As a consequence, there are some firms for which we have information on R&D effort, but whose output and input cannot be found in Financial Statements Statistics. In those cases we have used another source of output and input information, namely *Business Taxation Register data* (data 3), which is a data set on enterprises that has been collected for taxation purposes. It includes the profit and loss accounts as well as the balance sheets of basically all firms in Finland. This data source has some erroneous information, though. We have therefore excluded those firms whose information is evidently inconsistent. To take an example, we have dropped all those firms, where the sub-totals do not add up to the total. Unfortunately, taxation information is not available before 1994. If this source had been available also for earlier years, we would have been able to include a larger sample of R&D intensive service sector firms in the analysis.

After having linked information on industry, owner, output and input for the firms that have appeared at least once in the sample of the R&D survey, we constructed a basic data set for the analysis (data 5). Then we linked information from the *Innovation Survey* (data 6) and the firm-level file obtained from *Register-based Employment Statistics* (data 7). All the linking mentioned above has been done by using firm identification codes. In addition, we have added some industry-level information on prices, factor shares, and R&D intensity from *the ANBERD database* (item 8 in the graph). Finally we have processed the data for analysis purposes (item 9). We have calculated real value added, constructed labour and total factor productivity indicators, and have taken the calculated 2-year and 4-year periods for some variables in the final data set (data set 10).

Time periods:

The R&D survey has been carried out bi-annually from 1985 to 1995. Data on output and labour and capital inputs cover the period from 1986 to 1996. Register-based Employment Statistics is available since 1988. For this study we have used information from the Business Register since the year 1988. However, information on ownership is not available before the year 1989.

Variables:

Variable	Description	Source
Y	Value added in 1990 prices, deflated with an implicit price index of production at 2-digit industry-levels obtained from the National Accounts	2 (4)
L	Number of employed	2 (3)
K	Value of tangible assets in 1990 prices, deflated with an implicit price index of the capital stock at 2-digit industry-levels obtained from the National Accounts	2 (4)
Q	Nominal sales	1 (2)
TFP	Total factor productivity (definition in the text)	
R	Nominal expenditures on research and development	1
RP	Privately financed research and development expenditures, in nominal terms	1
RG	Publicly financed research and development expenditures, in nominal terms	1
RGTEK	Research and development expenditures financed by Tekes	1
RGOT	Publicly financed expenditures on research and development other than those financed by Tekes	1
RDINT	R&D expenditures per output in the industry	7
IPROS	Dummy variable indicating process innovation in the past three years	5
IPROD	Dummy variable indicating product innovation in the past three years	5
SKILLT	Share of the firm's workforce with a completed higher education (excl. post-graduate degrees) in the field of engineering and natural sciences	6
SKILLO	Share of the firm's workforce with a completed higher education (excl. post-graduate degrees) in other fields than engineering or natural sciences	6
FOROWN	Dummy variable indicating foreign ownership (the share of foreign owners at least 50%)	3
SIZE	Variable that indicates the size of the firm. Size is determined according to the average number of employees in the years *t* and *t*–2. Size classes: 1: small, $50 > \overline{L}$ 2: medium, $250 > \overline{L} \geq 50$ 3: large, $\overline{L} \geq 250$	2 (4)
SECTOR	1: Service sector (dummy variable *SERV*) 2: Construction, mining and electricity (dummy variable *CME*) 3: Manufacturing (dummy variable *MANU*)	3

Appendix 2. R&D intensity of the industries

R&D expenditure per nominal value of production, %

Industry	1985	1987	1989	1991	1993	1995
Mining, quarrying	0.32	0.44	0.68	0.77	0.37	0.22
Food, beverages and tobacco	0.32	0.40	0.51	0.75	0.57	0.47
Textile, apparel and shoes	0.15	0.32	0.30	0.78	0.48	0.54
Wood and products	0.19	0.22	0.21	0.30	0.17	0.37
Paper and printing	0.42	0.47	0.54	0.82	0.55	0.45
Industrial chemicals	1.94	2.64	3.10	3.16	2.76	2.24
Other chemicals (incl. medicines)	11.20	13.23	12.88	11.99	15.17	16.53
Petroleum	0.44	0.51	2.05	1.08	0.78	0.62
Rubber and plastic	1.58	3.39	1.64	2.85	2.02	2.83
Non-metallic minerals	1.10	1.02	1.31	0.87	2.06	1.80
Basic metals	0.71	0.83	0.71	1.03	0.72	0.67
Machinery etc.	2.97	3.26	3.56	4.04	3.73	3.93
Other manufacturing	1.55	0.80	0.98	1.76	1.81	1.31
Electricity, gas and water	0.32	0.44	0.68	0.77	0.37	0.22
Construction	0.03	0.03	0.07	0.07	0.13	0.13
Transportation	0.01	0.01	0.02	0.01	0.05	0.07
Communication	0.57	0.93	1.36	0.74	4.10	1.73
Business services	0.11	0.18	0.16	0.22	0.20	0.25
Trade etc.	0.04	0.06	0.05	0.04	0.04	0.05

Source: *ANBERD database, OECD and Finnish R&D Statistics*

Appendix 3. Regression estimates

Table A1. Models for two-year labour productivity growth using Cobb-Douglas function

	Model (1)		Model (2)		Model (3)		Model (4)		Model (5)		Model (6)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**1.738**	25.21	**1.731**	25.20	**1.731**	25.19	**1.757**	26.10	**1.740**	25.23	**1.731**	25.15
ln(Y/L)	**-0.284**	-23.83	**-0.290**	-24.34	**-0.290**	-24.32	**-0.294**	-25.19	**-0.285**	-23.87	**-0.290**	-24.27
dln(K/L)	**0.079**	9.43	**0.079**	9.44	**0.079**	9.44	**0.079**	9.53	**0.079**	9.48	**0.079**	9.45
dln(L)	**-0.069**	-5.44	**-0.071**	-5.58	**-0.071**	-5.58	**-0.083**	-6.69	**-0.069**	-5.42	**-0.071**	-5.57
R/Q	-0.065	-0.54	-0.193	-1.59								
RP/Q					-0.200	-1.25	-0.193	-1.20				
RG/Q					-0.173	-0.52						
RGTEK							-0.248	-0.59				
RGOT							-0.088	-0.15				
RDINT			**2.123**	5.82	**2.125**	5.80	**2.133**	5.83			**2.117**	5.64
R/Q*SERV									-0.231	-1.41		
R/Q*CME									0.259	0.36		
R/Q*MANU									0.112	0.63		
RP/Q*SERV											-0.239	-1.09
RP/Q*CME											0.276	0.30
RP/Q*MANU											-0.188	-0.76
RG/Q*SERV											-0.191	-0.49
RG/Q*CME											0.189	0.09
RG/Q*MANU											-0.152	-0.24
N	4760		4760		4760		4760		4760		4760	
R^2	0.179		0.185		0.185		0.185		0.179		0.185	

Notes: Coefficients in **bold** are significant at the 95% confidence level, and those underlined at the 90% level. All models include dummies for period, size and sector. *N* gives the number of observations. (These notes apply also to Tables A2, A3, A4 and A5.)

Continue

	Model (7)		Model (8)		Model (9)		Model (10)		Model (11)		Model (12)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**1.673**	23.25	**1.712**	23.72	**1.736**	19.99	**1.399**	8.03	**1.400**	8.06	**1.575**	9.01
ln(Y/L)	**-0.286**	-22.55	**-0.294**	-23.03	**-0.281**	-20.16	**-0.232**	-7.71	**-0.232**	-7.72	**-0.282**	-9.09
dln(K/L)	**0.075**	8.51	**0.074**	8.36	**0.088**	9.09	**0.122**	5.16	**0.125**	5.31	**0.142**	6.10
dln(L)	**-0.068**	-4.71	**-0.060**	-4.16	**-0.045**	-2.94	**-0.111**	-3.10	**-0.116**	-3.21	**-0.115**	-2.82
R/Q	**-0.413**	-3.14					**-1.561**	-5.13	**-1.631**	-5.33	**-2.292**	-7.11
RP/Q			**-0.610**	-3.40								
RG/Q			-0.240	-0.64								
RDINT	**2.237**	6.01	**1.862**	4.84	**1.979**	4.79	**3.496**	4.45	**3.268**	4.13	**2.063**	2.50
SKILLT	**0.174**	3.67										
SKILLO	**0.214**	2.77										
DSKILLT	-0.140	-1.64										
DSKILLO	**0.478**	3.57										
FOROWN					**0.061**	2.22						
FOROWN*(R/Q)					-0.190	-1.44						
DOMESTIC*(R/Q)					-1.009	-1.63						
IPROS									**-0.076**	-2.51		
IPROD									**0.071**	2.20		
IPROS*SERV											-0.333	-1.87
IPROS*CME											.	.
IPROS*MANU											**-0.063**	-2.07
IPROD*SERV											-0.071	-0.81
IPROD*CME											0.034	0.20
IPROD*MANU											**0.084**	2.40
SKILLT*SERV			0.013	0.21							0.086	0.50
SKILLT*CME			0.479	1.67							1.708	0.91
SKILLT*MANU			**0.460**	5.56							**1.009**	5.57
SKILLO*SERV			**0.219**	1.96							**1.208**	2.85
SKILLO*CME			**2.538**	3.40							-3.419	-0.66
SKILLO*MANU			0.088	0.82							**0.840**	2.14
DSKILLT*SERV			-0.003	-0.02							**1.432**	2.18
DSKILLT*CME			-0.068	-0.25							0.300	0.10
DSKILLT*MANU			**-0.330**	-2.54							-0.482	-1.02
DSKILLO*SERV			**0.558**	3.17							-0.154	-0.19
DSKILLO*CME			-0.088	-0.15							1.151	0.56
DSKILLO*MANU			0.297	1.37							-0.723	-0.99
N	4163		4163		3590		721		721		718	
R^2	0.184		0.192		0.174		0.191		0.201		0.256	

Table A2. Models for two-year total factor productivity growth

	Model (13)		Model (14)		Model (15)		Model (16)		Model (17)		Model (18)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**0.544**	16.03	**0.520**	15.06	**0.520**	15.07	**0.520**	15.07	**0.546**	16.02	**0.527**	15.23
ln(TFP)	**-0.140**	-16.39	**-0.142**	-16.58	**-0.142**	-16.58	**-0.142**	-16.58	**-0.141**	-16.46	**-0.144**	-16.73
R/Q	0.009	0.07	-0.081	-0.58								
RP/Q					-0.167	-0.91	-0.169	-0.92				
RG/Q					0.172	0.45						
RGTEK							0.303	0.63				
RGOT							-0.077	-0.11				
RDINT			**1.499**	3.59	**1.523**	3.63	**1.521**	3.63			**1.603**	3.72
R/Q*SERV									-0.106	-0.57		
R/Q*CME									**1.746**	2.10		
R/Q*MANU									0.045	0.22		
RP/Q*SERV											-0.084	-0.33
RP/Q*CME											0.574	0.54
RP/Q*MANU											-0.360	-1.27
RG/Q*SERV											-0.134	-0.30
RG/Q*CME											**5.876**	2.37
RG/Q*MANU											0.521	0.70
N	4760		4760		4760		4760		4760		4760	
R^2	0.074		0.076		0.076		0.076		0.075		0.078	

Continue

	Model (19)		Model (20)		Model (21)		Model (22)		Model (23)		Model (24)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**0.486**	13.47	**0.494**	13.51	**0.537**	11.05	**0.464**	6.09	**0.524**	6.49	**0.508**	6.11
ln(TFP)	**-0.141**	-15.37	**-0.144**	-15.45	**-0.146**	-15.05	**-0.132**	-6.25	**-0.137**	-6.50	**-0.160**	-7.39
R/Q	-0.276	-1.80					**-1.450**	-4.36	**-1.462**	-4.39	**-2.111**	-6.03
RP/Q			**-0.481**	-2.29								
RG/Q			0.282	0.64								
RDINT	**1.507**	3.48	**1.569**	3.48	**1.438**	3.05	**3.588**	**4.16**	**3.502**	4.04	**2.620**	2.88
SKILLT	**0.226**	4.08										
SKILLO	-0.031	-0.34										
DSKILLT	**-0.269**	-2.73										
DSKILLO	**0.296**	1.96										
FOROWN					0.019	0.60						
FOROWN*(R/Q)					0.008	0.05						
DOMESTIC*(R/Q)					-0.558	-0.79						
IPROS									**-0.122**	-3.71		
IPROD									0.045	1.28		
IPROS*SERV											-0.331	-1.72
IPROS*CME											.	.
IPROS*MANU											**-0.108**	-3.28
IPROD*SERV											-0.051	-0.53
IPROD*CME											0.123	0.65
IPROD*MANU											0.041	1.08
SKILLT*SERV			**0.217**	3.10							**0.520**	2.73
SKILLT*CME			**0.862**	2.54							-0.078	-0.04
SKILLT*MANU			**0.237**	2.48							**0.965**	4.92
SKILLO*SERV			0.059	0.45							**1.328**	2.88
SKILLO*CME			-0.338	-0.39							0.130	0.02
SKILLO*MANU			-0.106	-0.85							0.631	1.49
DSKILLT*SERV			-0.253	-1.73							1.381	1.92
DSKILLT*CME			-0.223	-0.71							0.622	0.20
DSKILLT*MANU			**-0.376**	-2.47							-0.474	-0.92
DSKILLO*SERV			0.377	1.90							0.849	1.02
DSKILLO*CME			-1.177	-1.72							-1.268	-0.56
DSKILLO*MANU			0.424	1.67							-0.129	-0.16
N	4163		4163		3590		721		721		718	
R^2	0.079		0.082		0.081		0.086		0.104		0.161	

Table A3. Models for two-year productivity growth, with size interactions

Dependent variable	Dln(Y/L) Model (25)		Dln(Y/L) Model (26)		Dln(Y/L) Model (27)		Dln(TFP) Model (28)		Dln(TFP) Model (29)		Dln(TFP) Model (30)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**1.756**	22.38	**1.913**	22.52	**1.713**	8.52	**0.670**	15.87	**0.650**	13.53	**0.566**	5.24
ln(Y/L)	**-0.287**	-21.34	**-0.326**	-22.1	**-0.300**	-8.94						
ln(TFP)							**-0.188**	-17.30	**-0.196**	-17.00	**-0.196**	-7.68
DLN(KL)	**0.051**	5.57	**0.053**	5.44	**0.143**	5.54						
dln(L)	**-0.058**	-3.40	**-0.059**	-3.03	**-0.109**	-2.07						
R/Q*SMALL	-0.022	-0.10	-0.451	-1.86	-1.050	-1.43	0.050	0.20	-0.196	-0.68	-0.828	-1.03
R/Q*MEDIUM	-0.637	-1.90	**-1.699**	-4.33	**-4.938**	-6.69	**-0.981**	-2.47	**-1.627**	-3.47	**-4.682**	-5.84
R/Q*LARGE	0.038	0.11	-0.520	-1.12	-0.824	-1.15	-0.205	-0.48	-0.753	-1.36	-0.936	-1.20
RDINT*SMALL	**2.904**	5.35	**2.879**	5.05	**5.049**	2.08	**2.280**	3.56	**2.248**	3.30	4.711	1.77
RDINT*MEDIUM	**2.830**	4.93	**2.425**	3.76	**5.846**	4.05	**2.623**	3.86	**2.500**	3.24	**6.425**	4.06
RDINT*LARGE	0.308	0.49	0.021	0.03	-0.550	-0.47	**2.071**	2.78	**2.378**	2.80	1.610	1.24
SKILLT*SMALL			**0.327**	3.26	**1.156**	3.77			0.098	0.83	**1.347**	4.03
SKILLT*MEDIUM			**0.853**	5.53	**0.779**	2.41			**0.551**	3.02	0.374	1.08
SKILLT*LARGE			**0.640**	2.67	**1.013**	2.67			0.417	1.46	**0.979**	2.37
SKILLO*SMALL			-0.019	-0.17	-0.432	-0.36			-0.070	-0.52	-0.102	-0.08
SKILLO*MEDIUM			**0.687**	2.96	**1.945**	3.27			0.314	1.14	**1.493**	2.33
SKILLO*LARGE			0.339	0.9	0.596	0.99			-0.122	-0.27	0.453	0.70
DSKILLT*SMALL			**-0.304**	-2.32	-0.324	-0.49			**-0.332**	-2.11	-0.739	-1.02
DSKILLT*MEDIUM			-0.423	-1.29	-0.542	-0.54			-0.719	-1.84	-0.448	-0.41
DSKILLT*LARGE			-0.307	-0.47	-1.140	-1.15			0.309	0.40	-0.222	-0.21
DSKILLO*LARGE			0.320	1.41	0.136	0.12			**0.598**	2.21	-0.088	-0.07
DSKILLO*MEDIUM			-0.171	-0.32	-1.688	-1.17			-0.402	-0.63	-1.283	-0.82
DSKILLO*LARGE			0.656	0.94	0.223	0.13			0.126	0.16	1.724	1.07
IPROS*SMALL					-0.076	-0.99					-0.131	-1.56
IPROS*MEDIUM					**-0.097**	-2.31					**-0.143**	-3.13
IPROS*LARGE					-0.034	-0.64					-0.080	-1.39
IPROD*SMALL					0.106	1.36					0.004	0.04
IPROD*MEDIUM					**0.096**	1.99					0.060	1.15
IPROD*LARGE					0.074	1.08					0.090	1.20
SMALL	**-0.142**	-6.19	**-0.107**	-3.67	-0.147	-1.48	0.049	1.85	**0.099**	2.84	0.043	0.40
MEDIUM	**-0.080**	-3.60	**-0.085**	-2.81	-0.120	-1.38	**0.054**	2.08	**0.071**	1.97	0.077	0.81
N	3403		3111		623		3403		3111		623	
R^2	0.183		0.215		0.282		0.110		0.122		0.201	

Table A4. Models for two-year labour productivity growth using Cobb-Douglas function, period 1994–96 excluded

	Model (1*)		Model (2*)		Model (3*)		Model (4*)		Model (5*)		Model (6*)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**1.675**	19.24	**1.671**	19.20	**1.673**	19.22	**1.675**	19.23	**1.682**	19.29	**1.679**	19.26
ln(Y/L)	**-0.274**	-17.39	**-0.276**	-17.52	**-0.277**	-17.54	**-0.277**	-17.55	**-0.275**	-17.45	**-0.277**	-17.57
dln(K/L)	**0.064**	6.13	**0.079**	9.44	**0.064**	6.16	**0.063**	6.14	**0.064**	6.17	**0.064**	6.17
dln(L)	**-0.046**	-3.03	**-0.046**	-3.01	**-0.047**	-3.05	**-0.048**	-3.11	**-0.046**	-2.99	**-0.047**	-3.07
R/Q	<u>0.333</u>	1.73	0.224	1.13								
RP/Q					0.386	1.56	-0.193	-1.20				
RG/Q					-0.620	-0.78						
RGTEK							-1.441	-1.30				
RGOT							0.284	0.24				
RDINT			**0.993**	2.16	**0.960**	2.08	**0.970**	2.10			**2.117**	5.64
R/Q*SERV									-0.017	-0.05		
R/Q*CME									1.200	1.43		
R/Q*MANU									<u>0.470</u>	1.89		
RP/Q*SERV											0.367	0.86
RP/Q*CME											<u>0.679</u>	1.79
RP/Q*MANU											0.201	0.63
RG/Q*SERV											-1.455	-1.34
RG/Q*CME											-2.085	-0.70
RG/Q*MANU											0.986	0.78
N	2849		2849		2849		2849		2849		2849	
R^2	0.191		0.192		0.192		0.193		0.191		0.194	

Table A5. Models for two-year labour productivity growth using Cobb-Douglas function, period 1994–96 excluded

	Model (7*)		Model (8*)		Model (9*)		Model (10*)		Model (11*)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	**1.693**	18.02	**1.752**	18.54	**1.704**	15.58	**1.470**	4.51	**1.371**	4.12
ln(Y/L)	**-0.284**	-16.38	**-0.299**	-17.06	**-0.274**	-15.19	**-0.270**	-4.52	**-0.256**	-4.25
dln(K/L)	**0.052**	4.65	**0.052**	4.58	**0.075**	6.20	**0.130**	3.41	**0.136**	3.55
dln(L)	**-0.038**	-2.14	-0.025	-1.37	**-0.051**	-2.77	-0.020	-0.41	-0.025	-0.50
R/O	0.182	0.82					-0.261	-0.37	-0.257	-0.37
RP/O			-0.013	-0.04						
RG/O			-0.524	-0.61						
RDINT	**1.259**	2.59	0.617	1.24	**1.204**	2.27	2.250	1.64	2.178	1.59
SKILLT	0.041	0.55								
SKILLO	**0.380**	3.26								
DSKILLT	**-0.547**	-3.96								
DSKILLO	**0.667**	2.94								
FOROWN					**0.061**	2.22				
FOROWN*(R/O)					-0.709	-0.70				
DOMESTIC*(R/O)					0.241	1.01				
IPROS									-0.072	-1.51
IPROD									0.082	1.32
IPROS*SERV										
IPROS*CME										
IPROS*MANU										
IPROD*SERV										
IPROD*CME										
IPROD*MANU										
SKILLT*SERV			**-0.235**	-2.52						
SKILLT*CME			0.257	0.52						
SKILLT*MANU			**0.601**	4.65						
SKILLO*SERV			0.305	1.54						
SKILLO*CME			0.109	0.07						
SKILLO*MANU			**0.340**	2.40						
DSKILLT*SERV			**-0.575**	-2.88						
DSKILLT*CME			0.761	1.14						
DSKILLT*MANU			**-0.697**	-3.46						
DSKILLO*SERV			**0.916**	2.77						
DSKILLO*CME			-0.454	-0.38						
DSKILLO*MANU			0.361	1.14						
N	2374		2374		2241		279		279	
R^2	0.198		0.211		0.191		0.137		0.148	

Chapter 4

JOB CREATION BY SUPPORTING TECHNOLOGY ADVANCES? – EVIDENCE FROM FINNISH PLANTS

Mika Maliranta

Acknowledgements: The data were constructed and analysed in the premises of Statistics Finland following the terms and conditions of confidentiality. I thank the Business Structures Unit for co-operation, and especially Merja Kiljunen for help with the data sets. Acknowledgements for helpful comments are due to Rita Asplund, Petri Böckerman and Pekka Ilmakunnas. Of course, I am solely responsible for the conclusions and any remaining errors.

1 Introduction

The creation of new technologies is the pre-requisite for long-run economic growth. Firms introduce new methods of production, new products, new sources of supply and new forms of organisation in pursuing profits in competitive markets. Some businesses manage and some fail to achieve high-quality technology and high productivity performance. In a competitive environment, the former tends to capture and the latter to lose markets. As a result, market economies are in a state of continuous turbulence. Joseph A. Schumpeter (1942) described this process as "creative destruction". It originates from the perception that some firms create new jobs while others concurrently destroy existing ones. Occasionally it is argued that in a competitive environment jobs can be created and maintained mainly with advanced technologies.

The analysis reported in this chapter attempts to shed light on the role of technology for job creation at the plant level in Finnish manufacturing and services, that is, at the level where workplaces locate and production takes place. We also examine worker flows from and into unemployment and the dependence of these flows on technology. These issues are considered primarily from the standpoint of policy-making since they are of crucial importance for a country plagued by persistently high unemployment. While Finland is still struggling with the aftermath of the deep recession of the early 1990s, R&D expenditures as a share of GDP have increased rapidly. This trend has been widely saluted and also promoted by substantial public subsidies, which reflects the high expectations put on this development. Proper evaluation of the consequences of pursued R&D policies from the employment point of view requires in-depth examination of the role of high productivity and R&D efforts for job creation and destruction. Sound policy tuning takes into account the fact that the net change in employment is dependent not only on job creation but on job destruction as well. Thus, we should be concerned with both the capacity to create new jobs and to maintain the existing ones.

The goal of both privately and publicly financed R&D expenditures is to improve productivity through technology advances, and thereby enhance the firm's ability to use labour and other inputs more profitably and competitively. To the extent public support for R&D expenditures affects or is expected to affect the productivity of firms in the future, this policy tool is likely to have a positive impact on employment.

The ability to create or maintain jobs may not depend solely on the firm's R&D efforts, though. Also, the magnitude of R&D activities at the industry level may play an independent and important role for the job creation of single firms. This might be the case if, for instance, the firm is able to appropriate knowledge spillovers originating from the R&D activities of other firms in the same industry and if this leads to improved ability to use labour input more profitably.[1] Thus, increased R&D efforts in a particular firm do not necessarily lead to job destruction within that industry but may, on the contrary, stimulate labour demand in low R&D intensity firms within the same industry. This being the case, the differences in the levels of R&D intensities across industries re-shape industry structures in favour of high-tech industries. However, it should be emphasised that there may be low technology (low R&D) plants (or firms) in the high-tech industries and vice versa. Technological progress may thus entail large-scale re-structuring also within industries.

One important feature of Finnish industrial policy is that it aims to strengthen the technological advantage of certain core industries by encouraging co-operation among firms operating within the same industry or cluster. Such policy actions are likely to benefit several firms in the same industry. While selective in granting support to different firms in the different industries, technology policy may have an important role not only in advancing technological progress but also in re-allocating employment. The net employment effect at the whole-economy level may be ambiguous, as a selective support strategy favouring some core industries may bring about some job destruction in the industries having relatively smaller stakes in the support.

However, in addition to the number of jobs also the quality of jobs is essential. Re-structuring processes tend to replace low-quality and low-wage jobs with higher-quality and higher-paid jobs. Technological progress may be biased in the sense that high-technology and high-productivity plants or jobs need to be occupied by skilled labour. This challenges the educational system. On the other hand, typically many expertise-demanding tasks need to be accompanied by auxiliary jobs with lower-skill requirements. Job security is another important dimen-

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[1] On the other hand, increased output (and employment) in a particular firm that is induced by public R&D support may bring about increased output (and employment) also among sub-contractors in the same industry having little or no R&D activities by themselves.

sion of job quality. The threat of becoming unemployed lowers the well-being of the person.

Nowadays it is frequently claimed that small firms are the engines of growth. This topic is also investigated here. In particular, we try to assess the role of technological spillovers within industries as well as the impact of firm's R&D efforts on job creation among small and medium-sized enterprises.

In order to explore the issues discussed above we have created a unique data set by merging data from several sources available nowadays for research purposes within the premises of Statistics Finland. We use firm-level information on output and labour from Financial Statements data and information on R&D expenditures from R&D surveys. We also make use of the innovation surveys carried out for the years 1991 and 1996. In addition, we use plant-level information on jobs and workers obtained from Finnish Business Register or derived from Employment Statistics by aggregating individuals at the plant level.

This analysis provides extensions in various dimensions to earlier work on the role of R&D effort and technology for job creation in Finland and elsewhere. First, so far most of the research undertaken in this field has investigated this issue using industry-level data that, moreover, have covered the manufacturing sector only. This study widens the scope to services, which have had an increasing role to play in the job creation process as well as the R&D efforts in the total business sector.[2] Second, as we use firm- or plant-level definitions of R&D intensity, we are able to take into account the fact that there may be substantial heterogeneity within industries in terms of technology. Third, we distinguish between privately and publicly financed R&D. Fourth, we supplement the analysis of job flows with an investigation of worker flows. In other words, we explore to what extent hiring and separation rates vary with the R&D intensity of firms. Finally, our fifth extension comes from the possibility to identify the source from where individuals are hired and the destination of individuals after separation. This affords an opportunity to study how worker flows from and into unemployment are associated with the R&D intensity of firms.

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2 According to R&D statistics of Statistics Finland, the Finnish service sector accounted for about 12% of R&D expenditures in the total business sector in 1985. In 1997 the corresponding figure was 17%.

The rest of the chapter is organised as follows. In Section 2 we introduce the definitions of job and worker flows applied and provide the theoretical background. Section 3 reviews some earlier empirical evidence on the subject. In Section 4 some descriptive analysis of job and worker flows is presented and discussed. An econometric analysis is performed in Section 5 and Section 6 concludes with a summary of the main findings and a discussion.

2 Job and worker flows

2.1 Key definitions

Job

We define, as commonly, a job as an employment position filled by a worker. For the purpose of analysing job creation and job destruction it seems natural to regard a specific physical location, where production of a certain type of products or services takes place, as an appropriate unit. This is a notable advantage compared to some studies using firm-level data, where the firm is an economic and legal unit that encompasses one or more establishments. Perhaps the most serious problem with this kind of data is that accurate longitudinal linkages are difficult to obtain due to sometimes complicated changes in ownership and organisation (acquisitions and mergers). Firm-level data have a tendency to overrate job flows[3] and presumably also the variation in the employment changes among units observed in the data.

Job flows

To begin with, we introduce the definitions of the job and worker flow measures used in this study. (Gross) job creation at time t equals employment gains summed over all plants that expand or start up between t–1 and t. Gross job destruction at time t, in turn, equals employment losses summed over all plants that contract or shut down between t–1 and t. Within the conceptual framework outlined above,

[3] This is demonstrated by Laaksonen and Teikari (1999) who investigate job flows by using both original firm-level observations and so-called synthetic firms. In the latter case mergers and take-overs that had occurred during the period under consideration were taken into account.

the same plant cannot, of course, simultaneously create and destroy jobs in a given period.[4] It is already a tradition in the literature of job and worker flows that the job creation rate among a group of units is obtained by dividing positive employment changes (ΔE^{+}) in the units by the average number of persons in periods t and t–1:

$$JC_t = \sum_i \Delta E_{it}^{+} / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1}\right)/2\right].$$

Analogously, the job destruction rate (*JD*) is defined as

$$JD_t = \sum_i \left|\Delta E_{it}^{-}\right| / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1}\right)/2\right],$$

where ΔE^{-} denotes a negative change in employment. The net rate of change in employment (net job creation) is the difference of these two values: $NET_t = JC_t - JD_t$. The sum of the job creation and the job destruction rate is the gross job re-allocation rate (*JR*)[5]: $JR_t = JC_t + JD_t$. The excess job re-allocation rate (*EJR*) is the difference of the gross job re-allocation rate and the absolute value of the net employment change (see Davis et al., 1996). This indicator provides us with a measure of the excessive job re-allocation that is not needed for a given employment change.

Worker flows

The linked employer-employee data allow us to decompose unit-level employment changes into worker flows. By comparing information in the two successive years, it is possible to calculate the number of persons who have entered (hired) a unit during the year (worker inflow) as well as the number of persons who have left the unit (worker outflow).

Moreover, with the detailed data in use it is possible to distinguish the inflows by source (employment in some other industry, unemployment, schooling, etc.) and the outflows by destination. More formally, we define the worker inflow rate as

$$WIF_t = \sum_i H_{it} / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1}\right)/2\right],$$

4 For a multi-unit enterprise, however, simultaneous job creation and destruction, as defined here, is possible.

5 This is also called the job turnover rate or the absolute job flow rate. It should be noted that at the unit level this is equal to the net employment change.

where H_{it} is the number of hired persons, i.e. those who were on the payroll of unit *i* in year *t* but not in year *t*–1. Similarly, we calculate the worker outflow rate as

$$WOF_t = \sum_i S_{it} / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1} \right) / 2 \right],$$

where S_{it} is the number of separated persons, i.e. those who worked in unit *i* in year *t*–1 but not in year *t*. The worker flow rate is the sum of the worker inflow and outflow rates: $WF = WIF + WOF$.

The difference of the worker flow rate and the job re-allocation rate, as defined above, is called the churning rate or the excessive worker turnover rate: $CHURN_t = WF_t - JR_t$ (Burgess et al., 1994). This gives the excessive worker turnover that is not needed to achieve a given job turnover. Both the excessive job re-allocation and the churning measures describe how dynamic the group of units under consideration is. They may also be interpreted as giving an indication of the insecurity that the individuals working in these units are facing. A better measure of insecurity, however, is one that shows the proportion of the employed that has ended up in unemployment:

$$WOFU_t = \sum_i SU_{it} / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1} \right) / 2 \right]$$

where SU_{it} is the number of persons who worked in unit *i* in year *t*–1, but were unemployed in year *t*. Analogously, we may calculate the worker inflow rate from unemployment:

$$WIFU_t = \sum_i HU_{it} / \left[\left(\sum_i E_{it} + \sum_i E_{i,t-1} \right) / 2 \right],$$

where HU_{it} is the number of persons who were hired into unit *i* from unemployment.

A great advantage of our comprehensive plant-level employer-employee data is that job and worker flows can be calculated in a consistent way. This means that the net rate of employment change (*NET)* is the difference of the job creation rate and the job destruction rate and also equal to the difference of the worker inflow rate and the worker outflow rate, i.e. $NET_t = JC_t - JD_t = WIF_t - WOF_t$. It should be noted that this property holds both at the aggregate level and at the unit level.

2.2 Job creation – a theoretical framework

In a capitalistic economy a major part of the hiring, investment and production decisions are made by firms that try to maximise profits:

$$\max \pi_i = p \cdot Y_i - costs_i ,$$

where Y_i is the output of firm i and p is the price of the output, which is the same for all firms. Output Y_i is determined by the total amount of input, which is a function of different input types, $f(L_i,K_i)$, and technology, A_i ,

(1) $Y_i = A_i \cdot f(L_i,K_i)$,

We note that the higher A_i is with given output and input prices and input quantities, the higher are the profits. The technological level of firm i can be measured (or at least estimated) using a productivity indicator defined as output quantity per input quantity, $A=Y/f(L,K)$. This can be proxied by the output to labour ratio.

To be more precise, the firm is maximising the present value of expected cash flows, which is determined by current and future productivity. Thus, current productivity and profitability are essentially dependent on investment and other decisions with long-lasting consequences that were made in the past. Economic activities are made in the continuously changing competitive environment where it is difficult to anticipate accurately the future prospects for profitable operations. It is hard to predict how rapid technological progress is going to be in the firm. The same uncertainty concerns the evolution of output and input prices. These are all essential for future profitability. Firms update continuously their expectations by new information obtained from markets. Large sunk costs and adjustment costs may be involved in investment as well as in hiring decisions. Furthermore, it may be difficult to find suitable labour quickly. All in all, we need to adopt a dynamic perspective on the firms' job creation and labour demand.

Even though firms (or plants) in the same industry may be producing the same products or services, and from that perspective have similar technology, it is important to realise the great heterogeneity that prevails within industries (see for example Davis et al., 1996; Jensen and McGuckin, 1997). Different firms produce products of different qualities. Quality differences between makes of the same product are manifested by the fact that consumers are willing to pay more for some make than for some other. Moreover, the same product may be produced in different ways. This heterogeneity is an outcome of the maximising behaviour of firms; they strive for competitive advantages, for example by means of R&D effort.

Firms of the same industry can be argued to have different technologies also when they share some common domain of the technology. Firms adopt different applications of the technology and they differ in their ability to use the technology. This generates variation in productivity levels within industries. We would expect that the performance of a particular firm, for example in terms of job creation, is dependent on industry as well as firm characteristics. The common domain of the technology is accumulated through experimentation and social learning (see Aghion et al., 1999) or through spillovers of technological knowledge that is produced within firms by their R&D effort. In other words, the level of technology in firm i, A_i, is not solely a function of the R&D effort made in the firm but may be expected to depend also on the total R&D stock in the industry. The cumulated experience in the firm and in the industry may be relevant as well.

Firms try to improve their technology by innovations, which can be classified into product and process innovations. Katsoulacos (1984), for example, argues that especially product innovations should have a favourable impact on employment through the increased demand that the innovator faces. As regards the consequences of the process innovations, the prediction of the final outcome is perhaps less clear-cut. The effect may be positive if the firm in question faces elastic demand and if the process innovation is not too labour saving relative to the other factors of production (see Klette and Førre, 1998). Moreover, the time span required for the realisation of the full effect on labour demand may vary between the two types of innovation.

Heterogeneity in technology and productivity levels across firms and plants is likely to lead to re-allocation of labour and other inputs. Firms or plants characterised by low productivity performance due to unsuccessful or insufficient R&D efforts are not able to preserve their jobs not to say to create new ones. The job creation capability may be low also because the capital stock consists of old vintages that are less productive than more modern ones. The re-structuring process that is needed to clean the markets from less efficient production units is an important element of technological progress. Furthermore, it may have implications that are important from the standpoint of society. This is because the re-allocation process compels individuals to change jobs, which entails costs and inconveniences of various kinds.

Caselli (1999) presents a model where technological progress entails the adoption of a new type of machines at the plants. A major point of the model is that when a skill-biased revolution occurs, induced for example by public R&D support, high-skilled workers will be the first to use the new machines since it is less costly for them to learn to use new machines efficiently. Low-skilled workers will continue to use the old machines. Of course, if the production with old machines is unprofitable at given relative input prices, a substantial investment might be needed to provide the low-skilled with the skills to meet the needs of the new technique.

The re-allocation process may involve worker flows into persistent unemployment especially among those who find it most costly to acquire modern skills. From a social point-of-view, it is desirable to achieve a new equilibrium smoothly with workers flowing from unemployment to modern plants to prevent the society from falling into the trap of high structural unemployment. The relationship between technological change, which is the goal of R&D activities, and unemployment is considered, for example, in a model by Aghion and Howitt (1994). In their search model the source of unemployment is labour reallocation across firms with technologies from different vintages. More specifically, there is the flow of workers into unemployment from the firms that have obsolete machines. The flow of workers out of unemployment occurs as a firm with a new machine is matched with an appropriate worker whose skills are adapted to that machine. The pool of unemployed who are seeking a match (i.e. job) increases as a result of the acceleration of technological change. Hence, analysing the worker flows from and into unemployment according to the technology characteristics of the firm or plant might give us an idea about the way an economy having experienced a technology shock (temporary acceleration of technical progress) re-shuffles employment through a temporary increase of the pool of unemployed.

A typical feature of various search models is that they assume one worker (and one skill type) per plant (firm). On the other hand, production of new types of products as well as new production techniques both typically require various kinds of tasks where the productivity effect of skills may vary. Kremer and Maskin (1996) incorporate this aspect in their model. This is to say that establishing a new modern plant may increase the demand for skilled as well as less skilled persons. What is important, the productivity of the less skilled may improve also without substantial upgrading of skills, the reason being that they are dealing with better techniques.

All in all, an important question is to what extent unemployment is a staging post in the process of transferring resources of an economy from low productivity plants to higher productivity ones.

3 Some previous findings

Previous empirical evidence on the role of technology and R&D for employment is not self-evident. Vainiomäki and Laaksonen (1997, 1999) have studied job creation and destruction in Finnish manufacturing in the turbulent period from 1987 to 1993. They also examine the role of technology in this process. Manufacturing plants were classified into high-technology, medium-high, medium-low and low-technology plants according to industry-based technology intensity definitions. Their analysis shows that in the high-technology group both job creation and job destruction rates were clearly higher than in the other groups. In net terms employment growth was clearly more favourable in the high-technology group than in the other groups. The low-technology group performed worst in this respect. As Vainiomäki and Laaksonen point out, their analysis ignores heterogeneity due to technological differences across plants within the four technology groups.

Technology and some other related features of changes in Finnish industry structures are documented by Pajarinen et al. (1998). They point out that Finnish employment has improved the most in the high-skill / high-wages / high-tech / high-knowledge industries. This study also overlooks the heterogeneity problem, that is, the fact that industries consist of various types of firms and production units that are likely to differ with respect to the attributes that were listed above. In support of that view, Parjanne (1997, 1998) finds that intra-industry changes in skill composition account for some 90% of the overall increase in the demand for high-skilled labour. As skills and technology are inevitably linked to each other, we have reason to believe that there is a substantial re-structuring process in full swing within industries.[6]

[6] Vainiomäki (1999a, 1999b) goes one step further by examining the plant-level changes in the educational composition of the labour force. Indeed, he finds that skills upgrading is dominated by increasing shares of skilled within plants. On the other hand, also the entry-exit effect has been important in relative terms, especially for the two highest (university-level) groups. In other words, new plants are typically high-skill intensive and exiting plants are usually low-skill intensive.

Industry is only one of the characteristics determining the job creation ability of a firm.

Maliranta (1997a) has analysed the evolution of aggregate productivity in Finnish manufacturing using plant-level data. Aggregate productivity changes are decomposed into various micro-level components. The analysis points out that there has been a substantial re-structuring process in operation. An important and increasing part of aggregate productivity growth originates from the tendency that plants with a high labour or total factor productivity level increase their relative share of employment and total input usage. As productivity and technological levels are closely related to each other, this finding could be interpreted as evidence in support of the views that the technological level of the production unit is important for net job creation.

The study by Maliranta (1997a) also reveals interesting differences over time and across industries. The contribution of the "re-structuring" component has increased substantially over time suggesting that the high performance level has been becoming increasingly important for net job creation. Re-allocation of labour and other inputs among plants has been particularly important in the textile industry and electrical machinery. The former can be described as the most typical sunset industry and the latter as the most typical sunrise industry in Finnish manufacturing. At the other extreme is the food industry with a re-allocation component having a negative rather than a positive contribution. Thus the role of high productivity and technology for net job creation may vary substantially depending on the characteristics of the economic environment that a firm or a plant is facing.

Contrasted to Finnish manufacturing, the role of technology for employment appears to be somewhat different in Norwegian manufacturing according to a study by Klette and Førre (1998). The job creation rate in high-technology industries does not seem to differ from that in the medium- and low-technology industries. The job destruction rate, in turn, seems to have been clearly higher in high-technology industries than in other industries since the latter part of the 1980s. As a result, net job creation was clearly worse in high-technology industries. The job re-allocation has typically been highest in high-tech industries. When categorising the plants according to the R&D intensity of the owner firm instead of the industry, the results remain qualitatively the same. Especially, as far as the period from the mid 1980s to 1992 is concerned, R&D intensive plants have not been successful in terms of creating and maintaining jobs.

Vainiomäki (1999a, 1999b) investigates using plant-level data how various technology indicators, capturing different aspects of technological change, are related to changes in the *composition* of the labour force in Finnish manufacturing plants. Results for educational shares suggest that the R&D intensity is positive for higher education and vocational education groups, but negative for lower university and basic education groups.

All in all, we do not know much about the role of R&D for job creation at the plant or firm level internationally and hardly anything as it regards to the Finnish economy. In particular, there seems to be a substantial shortage of knowledge about the impact of publicly financed R&D on job creation internationally and nationally.

4 Descriptive analysis of the role of R&D intensity for job and worker flows

4.1 Data

In the following analysis we will use four distinct data sources: Employment Statistics, Business Register data, R&D survey data, and Financial Statements survey data.

From Employment Statistics it is possible to derive plant-level information on the number of employees who have entered the unit, distinguished by source, as well as the number of workers who have left the unit, distinguished by destination. Furthermore, those workers who have stayed in the same unit during the whole period in question can be identified. Each plant has a unique identification code, which is used to calculate the flow rate measures introduced in Section 2 for single plants or for groups of plants. The plant-level data set used here was initially constructed for studies by Ilmakunnas and Maliranta (2000a, 2000b). It is called *Plant-level Employment Statistics on Job and Worker Flows* (PESF). It covers the years from 1988 to 1996.[7]

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[7] For this data set some information is linked from Business Register data. In principle, the data cover all employees in the non-farm business sector excluding fishing, hunting, forestry and social and personal services, like hairdressers and laundry services, as well as international organisations. However, in order to have consistent job and worker flow indicators those individuals were dropped who could not be

By using plant-specific codes we have traced the code of the owner firm and industry from the Business Register of plants. The size of the owner firm is obtained primarily from Financial Statements data. If, however, the firm is not included in the Financial Statements survey, we use information obtained from Business Register data. In order to avoid a "regression-to-the-mean-bias" (see Friedman, 1992) we have calculated the size by taking the average number of employees in the beginning (in t–1) and in the end of the period (in t).

Information on R&D intensity is linked from R&D survey data by using firm codes.[8] By this procedure we are able to classify the plants into groups according to the R&D intensity of the owner firm.[9] The R&D intensity of the plant is defined as follows:

Low:	1 % ≥ R&D intensity ≥ 0 %
Medium:	3 % ≥ R&D intensity > 1 %
High:	50 % ≥ R&D intensity > 3 %

Our definition of technology groups splits employment in our sample into the following proportions in total manufacturing: low technology accounts for one-half of employment while the medium technology group as well as the high technology group each covers about one-quarter.[10]

linked to a specific plant. Nevertheless, our plant-level data on job and worker flows cover more than 80% of total employment in the business sector. For more details about the data and the procedure by which they are constructed, see Ilmakunnas et al. (2000).

8 The owner firm of a plant is defined on the basis of year t. In the case of plant closure, however, the owner firm information is obtained from year t–1. In order to determine the technology group of the firm (and its plants) we have used the average R&D intensity of the firm in the years t and t–1.

9 The size of our sample of plants becomes somewhat smaller during the linking process. In manufacturing the sample plants for which we were able to define the technology group account for more than half of the total employment. As far as small (less than 50 persons) manufacturing firms are concerned our sample covers 5 to 10% of the employment. In services the corresponding share is quite small, too; 10 to 20% depending on the year. According to Business Register data small firms (employees less than 50) account for about one-fourth of total employment in manufacturing and about one-half in services (in 1996). Thus, especially in the case of the service sector (which is studied in Figure 3) the representativeness of our linked data set can be suspected (see text).

10 In services the corresponding shares are two-thirds for the low technology group and one-sixth for the medium and high technology groups.

It should be noted that R&D intensity is defined on the basis of the total R&D expenditures in the firm irrespective of "line of business". The same firm may have plants engaged in different industries, but we do not make a distinction between them. In other words, the same firm-specific R&D intensity indicator is used for all plants of the firm regardless of their industry (or sector). This approach is justified if there are economies of scope (see Klette and Førre, 1998; Klette, 1996).

4.2 Results

The job and worker flows by R&D intensity are illustrated in Figures 1–4.[11] The first figure shows the tendencies in the flows in manufacturing. The ticked line displays the development in total manufacturing. After the recession, the net job creation rate (*NET*) has been higher among R&D intensive plants than among lower R&D intensity plants. In other words, we may conclude that firms with a high R&D intensity have been most able to generate new jobs in net terms. Also the job creation rate (*JC*) and the worker inflow rate (*WIF*) (the latter is not shown here) have been relatively high among plants owned by high R&D intensive firms. *Figure 1* further reveals a clear downward trend in excess job re-allocation during the downturn[12], while in more recent years there are weak signs of an increase in the excess job re-allocation rate. This measure indicates the magnitude of simultaneous job creation and destruction (see Section 2). In other words, it seems that growth rates among plants have converged during the recession.

It seems that medium R&D intensity plants represent the most homogeneous group in terms of employment growth; the capacity to create new jobs tends to vary the most among high and low R&D intensity plants. While the net growth series suggest that high R&D intensity plants was the group which increased employment the most, the exces-

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[11] Ilmakunnas and Maliranta (2000b) note that job and worker flow figures calculated from PESF data are presumably biased upward to some extent in the years 1988–91 because of inaccuracies in links between plants and individuals. Since 1991 or 1992, however, job flows seem to accord quite closely with those calculated from the Business Register. This suggests that the latter part of our series is likely to give us an appropriate picture of tendencies. Besides, it should be noted that the main purpose of these figures is to compare the flows between the groups of plants in the different periods.

[12] See also Ilmakunnas and Maliranta (2000a, 2000b), who use the same data set. Vainiomäki and Laaksonen (1999) obtain similar results by using Industrial Statistics data instead of the Employment Statistics data used here.

sive job re-allocation measure reveals that there has been a lot of job destruction, too. Some high R&D intensity firms have been clearly less successful with their R&D efforts in terms of (net) job creation than others. One possible explanation for the finding that also the group of low R&D intensity plants is heterogeneous in terms of employment growth is that some low R&D intensity firms have been able to create jobs at a reasonable rate by substituting their own knowledge creation by knowledge appropriated from other firms or plants.

The churning rate measure describes another dimension of the "excessive" flows, viz. the magnitude of simultaneous hirings and separations at plants. Again we find a downward trend during the recession suggesting that labour markets became more rigid (see also Ilmakunnas and Maliranta, 2000a; 2000b). The churning rate among high R&D intensity plants has recovered remarkably after 1992 and had by 1996 achieved the level of the late 1980s. Thus, the great drive in net job creation among high R&D intensity plants in post-recession years has been accompanied by a relatively high degree of worker turnover. This finding may reflect that there is a large-scale matching process in operation in these plants. High-technology firms and plants have new types of tasks for which they are seeking suitable labour. At the same time, workers with high and modern skills try to find such jobs that best fit their abilities and desires. It seems that the economic recovery has made the Finnish labour market more flexible in this respect, too. Among low and medium R&D intensive plants the churning rate has remained at a low level also after the recession.

As a final point we examine how the flow rates into and from unemployment have varied over the years investigated. Figure 1 clearly shows the negative social consequences of the recession that hit the manufacturing sector in the early 1990s.[13] The recession was severe especially for those who worked in plants owned by relatively low R&D intensity firms. This observation is in line with recent studies for Finland using individual-level data, which report a substantially higher risk of becoming unemployed among manufacturing workers employed in low-tech industries and firms (Asplund and Lilja, 1999; Asplund, 2000). The figure further indicates that the flow rate into unemployment in-

[13] By comparing the flow rates in total manufacturing (ticked line) and in our three technology groups it is possible to conclude that flows to and from unemployment have been somewhat greater among plants excluded from the R&D survey. Thus, our sample does not seem to be fully representative in this respect. Small firms, which typically have higher flows from and to unemployment, are underrepresented in our linked data set.

creased more than sixfold in a few years' time among low and medium technology plants. Among high R&D intensity plants the increase was substantially more moderate.

Somewhat surprisingly the inflow rate from unemployment increased already in 1993, that is, during the recession (see also Asplund, 2000). On the other hand, as the pool of the unemployed was larger in the recession years it may have been easier for an employer to find suitable labour also among the unemployed (see also Pohjola, 1998). The inflow rate to manufacturing plants from unemployment culminated in 1994. Especially high and medium R&D intensity manufacturing plants absorbed unemployed persons.

There seems to be a new rise in the outflow rate to unemployment at the end of the period under consideration. The number of unemployed job applicants registered at the employment offices surged towards the end of the year 1996 (see Finnish Labour Review, 1999).[14] Indeed, especially the manufacturing sector experienced a "mini-recession" in 1996. Since then the downward trend in the unemployment rate has continued till the beginning of the year 2000.

A more detailed categorisation of plants according to the R&D intensity in manufacturing is used in *Table 1* for the purpose of summarising the main differences between R&D groups. It confirms our main findings made above. High R&D intensity plants create jobs in gross terms and especially in net terms. They are dynamic in terms of (excess) job re-allocation and churning. They have also had an important role in reducing unemployment after the recession.

Table 1. Average flows by R&D intensity in manufacturing, %, 1994–1996

R&D intensity	WIF	WOF	WF	JC	JD	JR	CF	EJR	NET	WIFU	WOFU	UNET	W
0 – 0.5 %	18.9	18.6	37.5	9.3	9.0	18.3	19.2	16.8	0.3	2.9	4.0	-1.1	27.0
0.5 – 1 %	16.9	18.9	35.8	8.1	10.1	18.2	17.6	16.1	-2.0	2.2	3.5	-1.3	27.9
1 – 2 %	17.5	11.8	29.2	10.3	4.6	15.0	14.3	9.3	5.7	3.8	2.6	1.2	15.3
2 – 5 %	17.1	14.0	31.1	9.8	6.8	16.6	14.5	13.6	3.0	3.4	2.2	1.1	15.1
5 – 50 %	32.7	22.2	54.9	18.6	8.2	26.7	28.2	16.3	10.4	4.0	1.5	2.5	14.7

Notes: UNET=WIFU–WOFU. W is employment share.

14 This register is the original source of the unemployment information in our data.

In *Figure 2* we examine the job and worker flows among small manufacturing firms. We find that high R&D intensity plants have created jobs in net terms at a slightly higher rate than lower R&D intensity plants on average during the period from 1988 to 1996. The average excess job re-allocation rate has been highest among low technology plants. Again we find that during recent years the churning rate has been highest among the high R&D intensity plants. Jobs in small and low-technology manufacturing firms appear to be especially risky; the worker flow rate into unemployment shown in Figure 2 demonstrates that jobs in a small and low R&D intensity manufacturing plant are particularly vulnerable during a slump (a more detailed analysis based on individual-level data is provided in Asplund, 2000). There was a notable increase in the outflow into unemployment after 1990 and this outflow rate was more than 16% in 1993 among low R&D intensity manufacturing plants of small firms. The flow of workers into unemployment was substantially lower from high R&D intensity plants.

The job and worker flows obtained for service sector plants are investigated in *Figure 3*. It should be noted that we focus only on those service plants whose owner firm has responded to the R&D survey. As the R&D survey covers only particular types of services (and firms), our sample of service plants is not representative of the whole service sector. There seem to be some extraordinary flow rates, which are out of the picture, especially for low R&D intensive plants. This does not, however, prevent us from gaining a general overview of the trends and differences between groups. It should be mentioned in this context that the figures for recent years are probably more reliable than those for earlier years and therefore deserve our main attention (see also footnote 11). One should be careful not to draw too strong conclusions from this analysis. The main focus here is on comparing flow rates in service sector plants differing in R&D intensity.

The ticked line showing the development in the total service sector, reveals that service sector employment increased in net terms since 1994. Despite a sharp decline in employment in the early 1990s, high-technology service firms were able to increase their employment in net terms almost in all years. The gross as well as net job creation rates have been poorest among low-technology service plants. Just as in manufacturing, also the service sector experienced a fair decline in the churning rate during the recession, suggesting that the labour market situation became more rigid due to the recession in the service sector as well. When contrasted to the service sector in general as well as to medium- and high-technology firms, low-technology service firms seem to have had exceptionally low turnover of workers. One might be tempted to argue that this is an indication of greater job security or stagnation. Our preferred measure of job security, however, does not give support for this conclusion. Worker outflow into unemployment was higher among low-technology service plants than among high-technology plants during the recession, and worker inflow from unemployment was lower during the whole recovery period.

Finally, in *Figure 4* we compare for the manufacturing sector features of job and worker flows among firms supported by the National Technology Agency (Tekes) to those of non-supported firms. For this purpose we have divided the manufacturing plants into three groups. We started by identifying the plants owned by firms that have obtained support from Tekes.[15] The other, i.e. non-supported firms, are classified into two groups: low R&D intensive, and medium and high R&D intensive. It should be noted that Tekes-supported firms account for a dominant share of the manufacturing labour force in our data (two-thirds in 1996). Moreover, there is a relatively small number of firms that are characterised by a high R&D intensity level but were not supported by Tekes.

The manufacturing firms supported by Tekes have been able to create jobs in net terms at a considerable rate since 1994. Worker outflow to unemployment has been clearly lower than among non-supported low R&D intensity firms. On the other hand, the firms supported by Tekes have hired unemployed persons at a lower rate than non-supported firms with medium or high R&D intensity.

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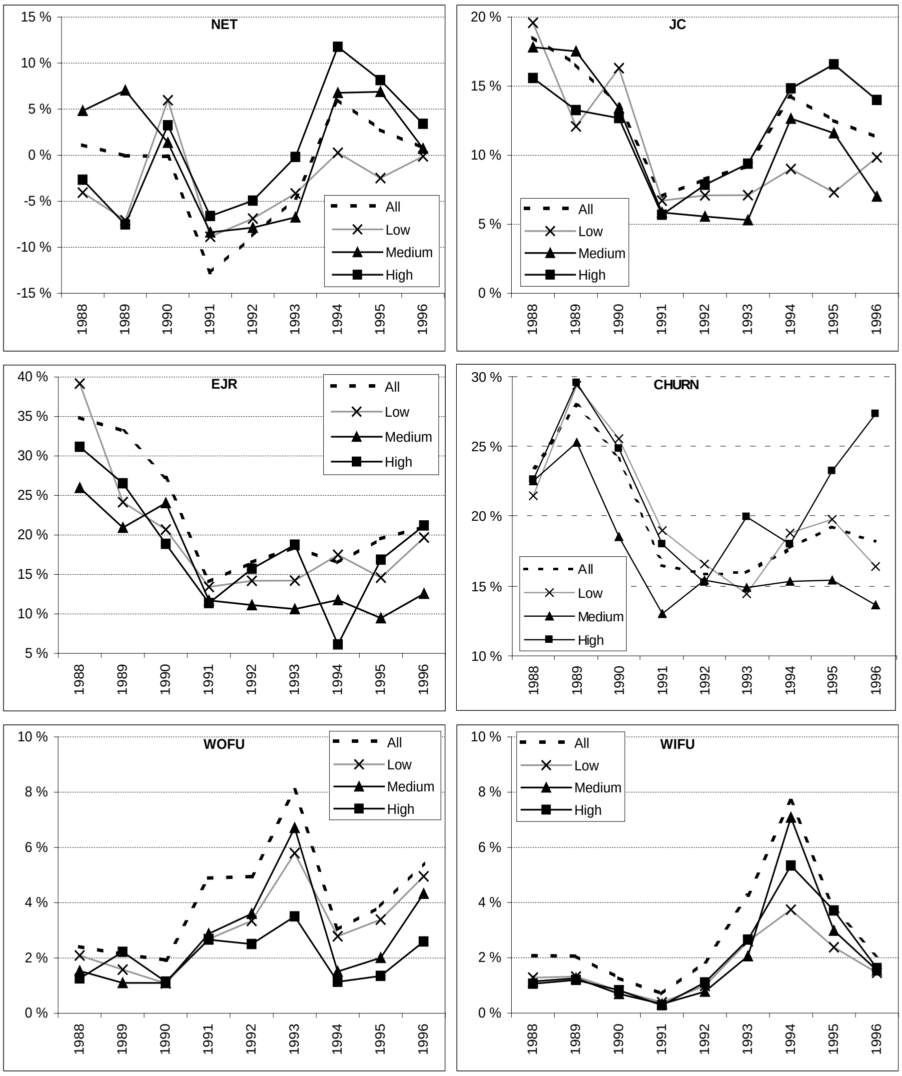
15 The identification was made possible by using firm register data maintained by Tekes.

Figure 1. Job and worker flows in manufacturing by R&D intensity



Notes: "All" refers to all plants in the plant-level data on job and worker flows (PESF). It covers all employees that are linked to a plant in Employment Statistics data. It includes also those plants, which were not linked with R&D survey data. Technology level groups are defined in the text.

Figure 2. Job and worker flows in manufacturing by R&D intensity, < 50 employees

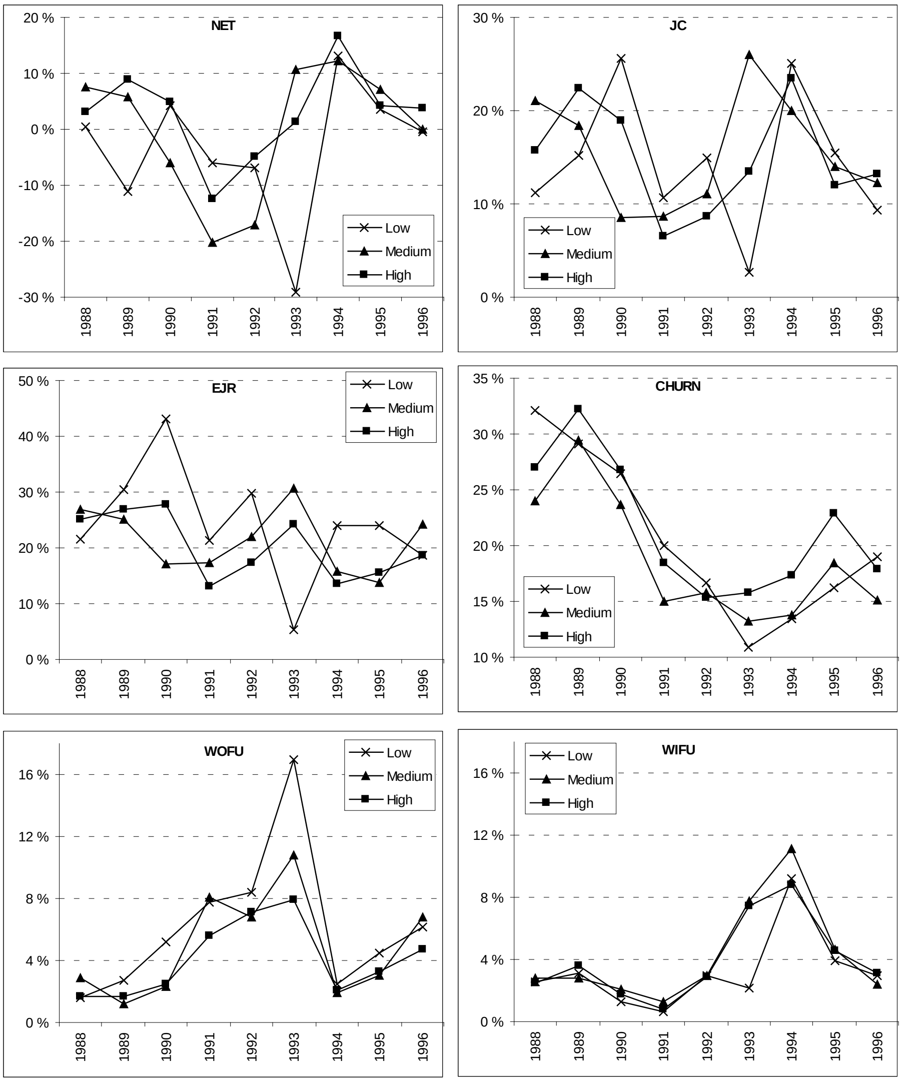
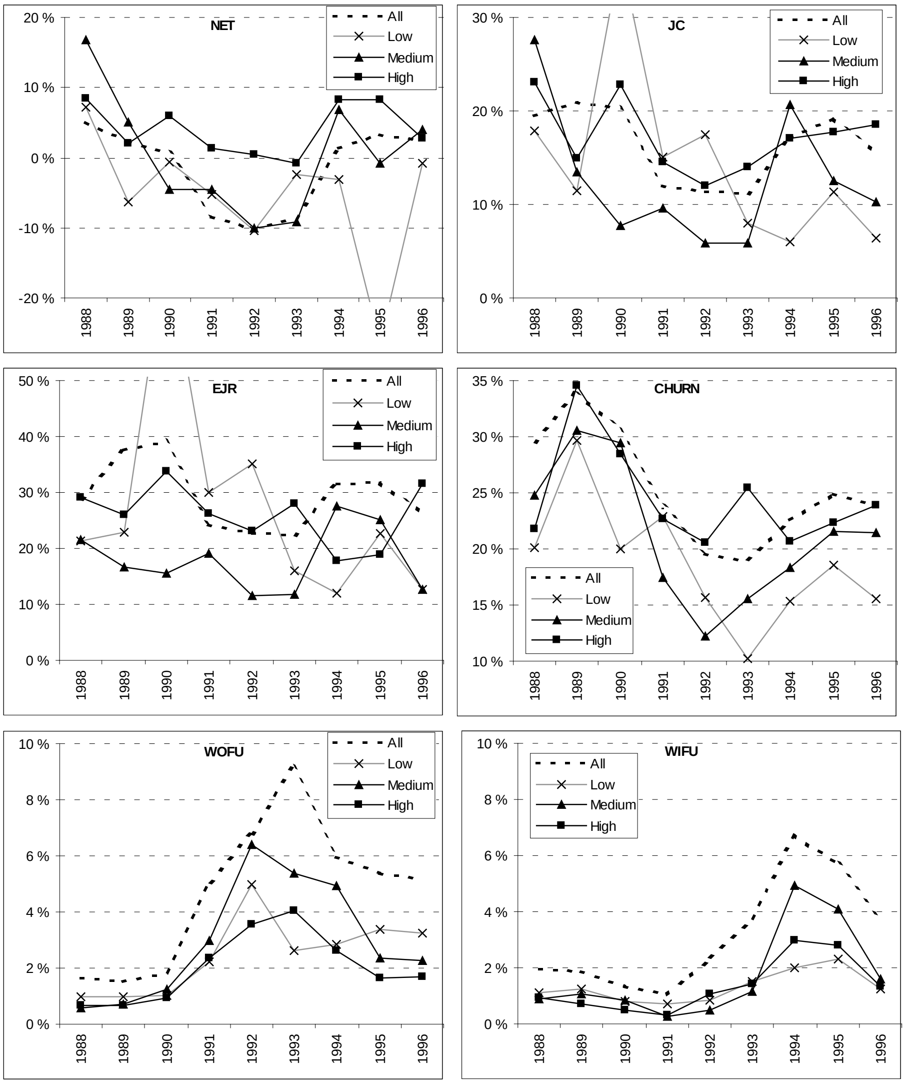
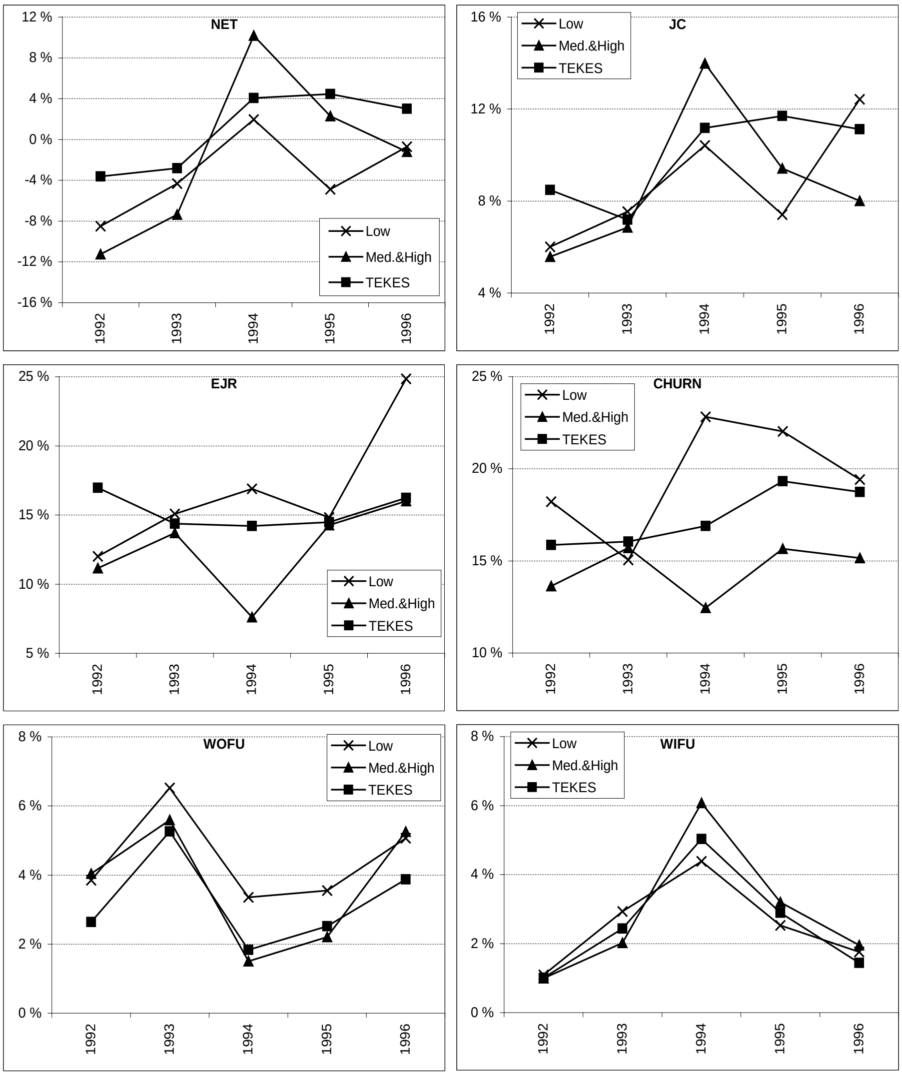


Figure 3. Job and worker flows in services by R&D intensity



Notes: "All" refers to all plants in the service sector in the plant-level data on job and worker flows (PESF). It covers all employees that are linked to a plant in Employment Statistics data. Other groups are defined in the text.

Figure 4. Job and worker flows in manufacturing by R&D intensity and Tekes support



Notes: Tekes denotes firms that have obtained support for R&D expenditures from the National Technology Agency. Other groups are defined in the text.

5 R&D intensity and job creation: some empirical evidence

5.1 Econometric modelling

Although the previous descriptive analysis with graphical displays is illustrative, it may miss important aspects, as many plant (or firm) characteristics potentially important for job creation are not accounted for simultaneously. These may distort our view on the factual role of R&D effort for employment. For example, firm R&D intensity may be related to the industry engaged in as well as the size or foreign ownership of the firm, all of which can be argued to be relevant factors of job creation or labour demand in itself. Regression analysis provides us a convenient tool to examine the role of plant and firm characteristics in greater detail. From now on we will concentrate on net job creation and disregard the question of worker flows.

In the subsequent analysis we are considering *two-year periods*. Then, the net job creation rate of firm (or plant) *i* in year *t* is measured as follows:

$$NET_{it} = \frac{E_{it} - E_{i,t-2}}{\left(E_i + E_{i,t-2}\right)/2}.$$

It should be noted that in this case both births (i.e. entries) and exits of firms (or plants) are well defined and take the value of 2 and -2, respectively. Given the limited range of this measure, -2 <= NET_{it} <= 2, it might be useful to transform it slightly. We apply the same method as Klette and Førre (1998), who use the definition

$$\tilde{NET}_{it} = \ln\left(\frac{c + NET_{it}}{c - NET_{it}}\right)$$

and choose arbitrarily $c = 4$.

Our econometric specification is of the following form:

$$\tilde{NET}_{it} = \alpha + \beta_{LP} \cdot \ln(LP_{i,t-3}) + \beta_{RD} \cdot \left(R_i / Y_i\right) + \beta_{RDINT} \cdot RDINT_I + \beta_F \cdot FOROWN_{i,t-1} + \beta_{IPROD} \cdot IPROD_{i,t} + \beta_{IPROS} \cdot IPROS_{i,t} + \lambda^s_{it} + e_{it}$$

where $LP_{i,t-3}$ is value added per employee (labour productivity) in the firm that owned plant *i*[16] in *t*–3 and *R/Y* is the firm's R&D expenditures divided by sales.[17] In some regression models we have divided the firm's R&D expenditures into a privately financed (*RP*) and a publicly financed (*RG*) component. *RG* is further split into expenditures financed by Tekes (*RGTEK*) and expenditures financed by some other government body (*RGOT*). λ^{s}_{it} denotes firm size dummies.[18] *FOROWN* is a dummy variable that captures the effect of foreign ownership. We have also included industry-specific year dummies.[19] As an alternative to industry-specific year dummies, year-specific industry R&D intensity indicators ($RDINT_I$) have been used.[20] When adding industry-level R&D intensity indicators to the model, year dummies are also included.[21]

We report regression results obtained by using employment-weighted[22] OLS. The models were also estimated with unweighted OLS, in which case the very small plants have exerted considerable influence on the results. As the so-called artificial deaths and births may be quite common especially among small plants we are exposed to the risk that these artificial deaths and births dominate the variation in our data. One way to escape this problem is to restrict the analysis solely to con-

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16 It should be noted that we have not measured the labour productivity level in the initial year (*t*–2) but in the year before that (*t*–3). We would like to investigate whether the labour productivity level in itself has a positive effect on net job creation in the longer term. Secondly, we control for the effect of the initial productivity level that is not available for firms that have entered by opening one or more plants during the period under consideration (these are so-called greenfield entries). As a consequence, these plants drop out from our sample, when the initial productivity level is controlled for in the model. This is simply because the initial productivity level is not available by definition.

17 More precisely, we have calculated the mean of non-missing R&D intensity in the years *t*–3 and *t*–1.

18 We have defined three size classes: small firms employing less than 50 persons, medium-sized firms with at least 50 employees but less than 250 and large firms employing at least 250 persons. The classification is based on the average size of the firm in the years *t* and *t*–2.

19 There are 19 industries and 5 time periods.

20 This variable is constructed in an analogous manner with firm R&D intensity levels, i.e. we have used the average R&D intensity in the years *t*–1 and *t*–3. Industry-level R&D intensities are shown in Appendix 2 in Chapter 3 of this volume.

21 We have not included fixed plant effects in any of our models, because values of some main variables do not vary at all or vary very little over time.

22 To be more precise, as weights we use plant size calculated by taking average size in the years *t*–2 and *t*.

tinuing plants ($|NET_{it}| \neq 2$). In that case the results obtained with unweighted OLS are qualitatively the same as those reported here.

5.2 Data

The dependent variable (net) job creation refers to the change in employment in the production unit (i.e. plant) as calculated from the Business Register on plants. Business Register data are superior to Employment Statistics data when measuring plant employment. One reason is that linking a person to a workplace is a challenging task that fails occasionally. As a consequence, there may be some measurement error in the plants' labour input numbers when summing over all individuals.[23] On the other hand, when using Business Register data as the source for measuring net job creation we are not able to investigate worker flows in a consistent way. Another difference compared to the data used in the descriptive analysis is that here employment measures the average full-time equivalent number of persons employed during the year whereas Employment Statistics data give the total number of employees, with no distinction made between full-time and part-time workers, and moreover, for the second week of December only.

Information on R&D expenditures, broken down by source of funding, is obtained from the R&D survey data. Supplementary information is taken from the innovation surveys carried out for the years 1991 and 1996. Information on the industry and owner of the firm is linked from the Business Register on firms[24] while plant-specific information on employment, industry and owner-firm is taken from the Business Register on plants. Value added and employment of the firm, which are needed for the calculation of the firm's labour productivity and size, are obtained from Financial Statements data. If the firm appears in the R&D survey

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[23] Ilmakunnas and Maliranta (2000a) have compared net changes in employment calculated from different data sources. They use plant-level Employment Statistics, i.e. the same source as in the descriptive analysis above, industrial statistics, national accounts and Employment Statistics. Although some differences can be found in the aggregate-level changes in employment, partly due to differences in definitions, all sources provide a relatively coherent view on the trends in *net* employment growth since the late 1980s. However, we found some differences in gross job creation and destruction numbers between PESF and Business Register data for the years 1988–1990 (see footnote 11).

[24] This is obtained from year *t* except in the case of plant closure when the information for year *t*–2 is used.

data but not in the Financial Statements data, value added is taken from the Business Taxation register data compiled for taxation purposes[25] and employment from the Business Register on firms. Finally, we have linked information on R&D intensity by industry group from the ANBERD database (OECD). Table A1 in the appendix of this chapter provides descriptive statistics on the variables of interest separately for manufacturing and services and for selected years.

5.3 Main findings of the regression analysis

First we report results for manufacturing plants. Then we study in greater detail the role of firm size in manufacturing by interacting variables of interest with the size dummies. Finally we study determinants of net job creation in the service sector.

5.3.1 Manufacturing

The results reported in *Table 2* show that the labour productivity level of the firm is positively associated with the subsequent net job creation at the plant level. The same holds true for the firm's total R&D efforts as well as the industry R&D intensity level, both of which are supposed to affect productivity positively at least in some day in the future. To the extent that R&D efforts have an immediate impact on the productivity level of the firm, this effect of R&D should be reflected in a positive coefficient estimate of the *ln(LP)* variable (see Chapter 3 of this volume). All in all, it seems that R&D intensity has a direct effect on subsequent job creation, conditional on the other factors kept constant.[26]

We have also interacted the R&D intensity of the firm with that of the industry, i.e. *RTOT*RDINT*, to see how these factors contribute to job creation together. The coefficient estimate of the interaction term turns out to be significantly negative. In other words, it seems that the relationship between the R&D intensity level of the plant and net job

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25 Unfortunately, these data cover the years since 1994 only.

26 We have also estimated models with the initial productivity level variable exluded. As a consequence, the number of observations increases somewhat. The relationship between job creation and R&D intensity becomes slightly stronger (results not reported here).

creation is stronger in the low R&D intensity industries than in the high R&D intensity industries.

In Model (2) the estimation is based on the variation within industries and periods, i.e. we have interacted 19 industry dummies with 6 period dummies. In this case the industry level R&D intensity variable is excluded from the model. Again the results indicate that the firm's R&D intensity has a positive effect on (net) job creation.

One should, however, be cautious in these interpretations. Being a long-term investment, R&D efforts can be supposed to reflect, among other things, positive future prospects of the firm that may be unobservable to the researcher. The realisation of these expectations may materialise as positive job creation. In other words, it is possible that a positive relationship between R&D intensity and future job creation does not signal solely a causal relationship. Instead, the fact that some firms decide to invest money into R&D activities may simply indicate good future prospects of the firms that meanwhile result also in job creation. Firms also obtain risk-free subsidies and loans for R&D activities, which might invite investments in projects of a more uncertain prospect. Therefore, it is of particular interest to investigate the impact of publicly financed R&D expenditures, isolated from the privately financed component. For this purpose the firm's total R&D expenditures have been divided into a privately (*RP*) and publicly (*RG*) financed component. The publicly financed part, in turn, has been split into financing obtained from the National Technology Agency (Tekes) (*RTEK*) and from some other public source (*RGOT*). The results suggest that publicly financed R&D efforts do not necessarily promote net job creation directly. It is only privately financed R&D expenditures per sales that are clearly positively associated with the future net job creation. Neither can we find any empirical support for the view that R&D support granted by Tekes has a direct independent stimulus on future job creation at the plant level.

Next we explore whether foreign-owned production units behave differently from domestic-owned ones as regards job creation. All in all, Model (4) is to a certain degree a disappointment to us. Relatively large standard errors prevent us from making conclusions on this matter. Furthermore, also the other coefficient estimates seem somewhat strange.[27]

[27] We have reason to believe that our measure of foreign ownership in our data is plagued by inaccuracy especially as far as earlier years are concerned.

The estimates of Model (5) suggest that process innovations are positively associated with subsequent job creation, whereas product innovations do not show a statistical relationship with our dependent variable. This is in conflict with what one might expect as process innovations generally aim to be input saving and product innovations output augmenting. On the other hand, it is not obvious what the timing of the innovation variable should be and what should be the length of the period under consideration. Our innovation variable indicates whether or not the firm has carried out an innovation in the past few years. In other words, the innovation is generally implemented during the same period for which we are measuring the rate of change in employment. We have also investigated the possibility of there being a time lag before the impact is realised by using $IPROS_{i,t-2}$ and $IPROD_{i,t-2}$ variables instead of $IPROS_{i,t}$ and $IPROD_{i,t}$. The coefficient estimates, however, do not differ from zero in a statistically significant way.

Table 2. Models explaining net job creation over two-year periods, manufacturing

	Model(1)		Model(2)		Model(3)		Model(4)		Model(5)	
	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value
Intercept	**-0.220**	-4.52	**-0.256**	-2.66	**-0.192**	-3.97	-0.066	-1.17	**-0.244**	-2.34
ln(LP)	**0.032**	3.88	**0.042**	4.63	**0.029**	3.59	0.008	0.93	**0.050**	2.80
RTOT	**1.013**	7.43	**0.401**	4.20			0.083	0.27	**0.909**	5.29
RP					**0.548**	5.31				
RGOT					2.029	1.87				
RGTEK					-1.041	-0.79				
RDINT	**1.507**	6.63			**0.728**	4.41	**0.822**	4.44	0.576	1.73
*RTOT*RDINT*	**-15.20**	-5.10								
FOROWN							0.002	0.13		
*FOROWN*RTOT*							-0.461	-1.44		
IPROS									**0.071**	3.89
IPROD									-0.008	-0.32
SMALL	**0.047**	2.80	**0.043**	2.62	**0.049**	2.92	**0.058**	2.78	0.027	0.43
MEDIUM	**0.043**	4.81	**0.040**	4.47	**0.047**	5.17	**0.044**	4.23	0.008	0.38
Industry-specific year dummies	no		yes		no		no		no	
Year dummies	yes		no		yes		yes		yes	
N	13156		13156		13156		9399		2089	
R^2	0.058		0.128		0.056		0.066		0.090	

Notes: Coefficients in **bold** are significant at the 95% confidence level, and those underlined at the 90% level. *N* gives the number of observations.

5.3.2 The role of firm size in manufacturing

In the previous analysis, with employment-weighted OLS, large firms dominated the results. The use of employment weights is logical from the perspective of total employment in a sector or an economy.[28] On the other hand, it is often argued that small firms are the engines of employment growth, at least in the longer run.[29] Although this view can be questioned (see for example Hohti, 2000; Ilmakunnas and Maliranta, 2000b), it is interesting to study more carefully how the factors of job creation ability vary by the size of the firm. More specifically, we have interacted variables with the size dummies to examine whether or not there is significant variation across differentially sized firms. As mentioned earlier, we distinguish between three size classes: small firms with less than 50 employees, medium-sized firms with at least 50 but less than 250 employees, and large firms with at least 250 employees.

The results are reported in *Table 3*. From Model (6) it is possible to conclude that high R&D intensity in the industry is of vital importance for net job creation especially for small and medium-sized firms. This suggests that externalities are especially important for smaller firms. Model (7), where industry-level R&D intensity is replaced by industry-specific year dummies, suggests that high productivity of the firm is particularly important for net job creation in smaller firms. All models reported in Table 3 seem to indicate that the firm's R&D intensity is critical for future net job creation mainly among larger firms. Model (8) repeats our earlier finding of R&D support obtained from Tekes not being significantly correlated with subsequent net job creation. On the other hand, subsidies and loans granted by other government bodies seem to be positively related with net job creation at least among large firms. For small and medium-sized firms the result is ambiguous because of large standard errors (and low *t*-values).

In sum, conditional on the interacted variables held constant in the model, small firms do no seem to have superior performance in terms of net job creation. Thus, small firms are not necessarily the engines of growth if they are engaged in the wrong industries (low R&D intensive

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[28] Put differently, the absolute impact on sectoral or whole-economy employment is larger when a large firm increases its employment by 5% compared to a small firm experiencing the same growth rate of employment.

[29] Hohti (2000) has investigated in greater detail how employment patterns and growth vary by plant size in the Finnish manufacturing sector during the period 1980–1994.

industries) or if their performance level does not meet the requirements of the competitive environment. We gain some evidence that process innovations are positively associated with future job creation especially among larger firms.

Table 3. Models with size interactions explaining net job creation over two-year periods, manufacturing

	Model(6)		Model(7)		Model(8)		Model(9)	
	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value
Intercept	**-0.226**	-4.15	-0.247	-1.59	**-0.227**	-4.17	**-0.303**	-2.93
ln(LP)							**0.049**	2.77
*ln(LP)*SMALL*	0.045	1.40	**0.077**	2.31	0.045	1.40		
*ln(LP)*MEDIUM*	-0.011	-0.64	**0.049**	2.35	-0.012	-0.68		
*ln(LP)*LARGE*	**0.036**	3.87	**0.038**	3.44	**0.036**	3.86		
*RTOT*SMALL*	0.042	0.11	0.039	0.11			-0.106	-0.07
*RTOT*MEDIUM*	0.336	1.30	0.079	0.31			0.612	1.04
*RTOT*LARGE*	**0.587**	5.55	**0.523**	4.79			**0.946**	5.28
*RP*SMALL*					-0.032	-0.06		
*RP*MEDIUM*					0.387	1.23		
*RP*LARGE*					**0.621**	5.39		
*RGOT*SMALL*					0.658	0.41		
*RGOT*MEDIUM*					3.113	1.29		
*RGOT*LARGE*					**4.444**	2.23		
*RGTE*SMALL*					-0.194	-0.10		
*RGTE*MEDIUM*					-0.945	-0.43		
*RGTE*LARGE*					-2.733	-0.84		
RDINT							<u>0.559</u>	1.67
*RDINT*SMALL*	<u>1.550</u>	1.79			<u>1.566</u>	1.81		
*RDINT*MEDIUM*	**1.937**	4.14			**1.946**	4.15		
*RDINT*LARGE*	**0.492**	2.71			**0.545**	2.94		
SMALL	-0.008	-0.04			-0.008	-0.04	0.023	0.24
MEDIUM	**0.277**	2.62			**0.281**	2.65	0.011	0.25
*IPROS*SMALL*							0.041	0.28
*IPROS*MEDIUM*							<u>0.066</u>	1.71
*IPROS*LARGE*							**0.072**	3.43
*IPROD*SMALL*							0.070	0.47
*IPROD*MEDIUM*							-0.002	-0.04
*IPROD*LARGE*							-0.010	-0.34
Industry and size	no		yes		no		no	
Year dummies	yes		no		yes		yes	
N	13156		13156		13156		2089	
R^2	0.057		0.140		0.057		0.091	

Notes: Coefficients in **bold** are significant at the 95% confidence level, and those underlined at the 90% level. *N* gives the number of observations.

5.3.3 Service sector evidence

In *Table 4* we report regression results obtained from our sample of service sector firms. The findings resemble strongly those obtained for manufacturing. The initial productivity level of the firm predicts future job creation quite well in the firm's plants as does also a high R&D intensity level. Net job creation turns out to be high when industry R&D intensity is high. On the other hand, the industry R&D intensity variable makes a distinction between four industries only, so too much weight should not be given to this finding. Moreover, our sample covers mainly those service industries and firms that are supposed to have R&D activities to a significant extent.[30]

Table 4. Models explaining net job creation over two-year periods, service sector

	Model(10)		Model(11)		Model(12)		Model(13)		Model(14)	
	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value
Intercept	**-0.453**	-11.57	**-0.391**	-9.39	**-0.423**	-10.97	**-0.342**	-6.51	**-0.679**	-4.88
ln(LP)	**0.082**	12.09	**0.073**	10.75	**0.077**	11.47	**0.070**	8.51	**0.112**	4.89
RTOT	**0.815**	7.93	**0.415**	5.68			**0.468**	2.97	**0.537**	3.79
RP					**0.573**	7.01				
RGOT					0.871	1.27				
RTEK					-0.205	-0.33				
RDINT	**5.177**	9.89			**3.818**	10.08	**5.028**	11.64	0.114	0.12
*RDINT*RTOT*	**-174.38**	-3.73								
FOROWN							**0.065**	3.95		
*RTOT*FOROWN*							-0.015	-0.08		
IPROS									-0.041	-1.78
IPROD									-0.003	-0.10
SMALL	**0.044**	3.00	0.012	0.78	**0.044**	2.95	**0.091**	4.66	0.041	0.69
MEDIUM	0.016	1.74	-0.005	-0.49	0.016	1.80	**0.035**	3.14	**0.079**	3.02
Industry-specific year dummies	no		yes		no				no	
Year dummies	yes		no		yes				yes	
N	18918		18918		18918		12421		1178	
R^2	0.033		0.051		0.032		0.041		0.059	

Notes: Coefficients in **bold** are significant at the 95% confidence level, and those underlined at the 90% level. *N* gives the number of observations.

[30] It is, however, worth reminding the reader that the industry group of our observation unit (the plant) is defined by the production activities performed in that production unit. Firms classified into the service sector may also have manufacturing plants, and vice versa.

Again, the empirical evidence suggests that privately financed R&D expenditures are positively related with net job creation. For public support, the evidence is weak, and especially for Tekes support. The relationship between the firm's R&D intensity and job creation turns out to be of the same magnitude among domestic- and foreign-owned plants, but according to Model (13) foreign-owned firms nevertheless seem to have created more jobs in net terms than domestic-owned firms. From Model (14) we infer that in the service sector process innovations are negatively rather than positively related with future job creation.

6 Summary and concluding remarks

Our analysis provides a fair amount of empirical evidence for Finnish manufacturing and services in support of the contention that high-technology firms are of considerable importance for job creation as well as for job sustainability. We use several indicators that capture different dimensions of high technology. These include the R&D intensity of both the firm and the industry as well as the firm's productivity level, which can be taken to be dependent on, among other things, the R&D efforts made in the past. We have examined the role of privately and publicly financed R&D efforts for job creation. Special attention has also been paid to the role of firm size in the job generation process.

Our descriptive analysis with graphical displays points to firms with high R&D intensity having been superior in net job creation over the past few years. However, the excess job re-allocation measure suggests that high R&D intensity plants have been more heterogeneous in terms of employment outcome. This is to say that, although high R&D intensity plants have generally had quite a favourable employment development, there has also been a relatively large amount of "excessive" job destruction within this group. This is in accordance with the view that there is a selection process in operation among these firms whereby those with successful R&D investments outperform and gain markets from those who failed in their R&D efforts. Excess job re-allocation is quite high also among plants with a low R&D intensity level. Although generally net job creation is relatively modest among these plants, some of them are nevertheless able to perform quite well. Possibly, they are able to substitute a low R&D effort with some other factor improving their job creation capacity; such as luck, experience or the ability to appropriate knowledge that is spilling over from other firms or plants.

In addition to the "excessive" turnover of jobs *among* high R&D intensity plants, we find "excessive" turnover of workers *within* high R&D intensity plants as well. To put it differently, our results for the past few years, in particular, indicate that there has been a relatively large amount of simultaneous hirings and separations at high R&D intensity plants. One possible explanation for this finding is an ongoing large-scale matching process among high-technology firms and plants fuelled by the introduction of new types of tasks for which they seek suitable workers. At the same time, workers with high and modern skills try to find jobs that best fit their abilities and desires. The recovery of the Finnish economy from the severe recession in the early 1990s has made the labour market more flexible in this sense.

During the recession the flow of workers into unemployment was substantially lower from high R&D intensity plants than from medium and low R&D intensity ones. This is in line with the idea that high R&D firms generally have more productive jobs and are more competitive. In addition, workers in these firms are likely to be more skilled and thus more productive. Moreover, high R&D intensity plants have absorbed unemployed individuals at a higher rate than lower R&D intensity plants.

A more detailed econometric analysis confirms our main findings from the descriptive analysis of job and worker flow rates among plants differing in R&D intensity of the owner firm. We find that high productivity of the firm has a positive impact on (net) job creation. Thus, factors contributing positively to productivity can be expected to generate new jobs in the future. A high R&D intensity level is found to have an independent positive effect on (net) job creation, also after controlling for productivity and some other background characteristics of the firm/plant. Hence, even if the firm's R&D effort had no productivity-inducing effect whatsoever in the short run (see Chapter 3 of this volume and Rouvinen, 1999), it might nevertheless have a positive and more immediate influence on (net) job creation. For example, if a firm or a plant with high R&D intensity anticipates high productivity performance in the future, it may determine its current labour demand against this prospect. Also, a high R&D intensity of an industry is positively associated with net job creation. Thus, also a firm with low R&D intensity and low productivity may do reasonably well in terms of job creation if engaged in an industry where the average R&D intensity level is high. Indeed, our results concerning the manufacturing as well as the service sector suggest that the relationship between the R&D intensity of the plant and its (net) job creation capacity is stronger in low than in high R&D intensity industries.

When the R&D intensity of plants is broken down into components of privately and publicly financed R&D, we find that the privately financed part is positively related with net job creation while the evidence for the publicly financed part is more ambiguous. In general, we do not obtain coefficient estimates of much statistical significance for publicly financed R&D because of large standard errors. One might expect that firms wish to receive public support especially for technology projects that are riskier than usual. Because of the large sunk costs involved in recruitment, firms may be watchful in their decisions when the outcome is uncertain. Our findings, however, do not suggest that R&D support is ineffective in terms of job creation as its effect may come out indirectly through inducing industry R&D expenditures. Moreover, it may encourage private R&D expenditures of the firm with positive consequences for job creation.

We obtain some evidence for high productivity being effective for job creation especially among small firms. Moreover, it seems that a high R&D intensity of an industry contributes positively to job creation among small and medium-sized firms, suggesting that spillover effects are important for smaller firms. As large firms account for a dominant share of total R&D expenditures in industries (see R&D statistics), it seems that smaller firms benefit from R&D activities of the large firms. Among large firms, on the other hand, the firm's R&D intensity seems to be important for job creation, but appears to have hardly any role among smaller firms.

This study has focused on the role of certain plant (and firm) characteristics, especially in terms of technology, in the process of job and worker flows without explicitly considering labour force characteristics. However, while we are also concerned with the question of how effectively high-technology firms can contribute to moderating unemployment, this issue is paid some attention in this context. Indeed, it may be argued that as R&D support aims to increase the technological level of firms, entailing increased demand for high skills, this tool seems to provide very little consolidation for the low-skilled unemployed.

Kremer and Maskin (1996) provide empirical evidence that growth in wage inequality in the United States, Britain and France has been accompanied by greater segregation of high- and low-skilled workers into separate firms. This is to say that it has become less common for high- and low-skilled workers to work in the same firm. This finding is even more interesting when considered in parallel with some other pieces of evidence concerning US manufacturing provided by Dunne et al.

(1999). Their plant-level analysis shows that both the dispersion in (log) wages and in labour productivity exhibits a sustained increase over the period 1975–1993. They also point out that there exists a positive cross-plant relationship in the level of wages and productivity as well as in the changes in wages and productivity. Moreover, Haltiwanger et al. (1999) find that US manufacturing plants having a highly educated personnel also tend to have high productivity. Putting these pieces together it seems that the US manufacturing sector has been characterised by a substantial segregation process. At one extreme of the distribution there are low-wage and low-productivity plants with less skilled workers. At the another extreme of the distribution there are high-productivity plants with high wages and highly skilled persons. These findings can be viewed as suggestive evidence that high-technology firms and plants are not the most probable to absorb low-skilled unemployed.

Finnish labour market institutions differ considerably from those of the United States. One distinctive difference between Finland and the USA is that wage dispersion is substantially lower in Finland. One likely consequence of wage compression is that low-productivity plants and firms that are not able to pay minimum wages are continuously cleaned away. Maliranta (1997a) provides evidence from Finnish manufacturing pointing to declining (employment-weighted) dispersion in productivity levels among plants since the late 1970s. This holds true for labour productivity as well as for total factor productivity. As one would expect, this trend seems to have been associated with the structural component of aggregate productivity growth, that is, the tendency of high-productivity plants increasing their labour share at the cost of low-productivity plants (see also Maliranta, 1997b).

Thus, in Finnish manufacturing an ever-decreasing number of persons are working in plants whose productivity level, and presumably also technological level, is considerably below the average. An inevitable question then arises: Is this tendency bound to mean an ever-decreasing amount of job opportunities for low-skilled and low-productivity individuals? Is the technological progress such that segregation is necessary in order to reach and maintain a reasonably low unemployment rate? These are crucial questions, as it seems that there is a wide reluctance in the Finnish society to allow substantial increases in wage inequality. As there are obvious limits for providing high and modern skills for each and everyone, it would be highly desirable that high-technology and high-productivity plants were able to provide jobs also for the low-skilled.

There are obvious risks involved with segregation from the standpoint of economic growth, as pointed out by Kremer and Maskin (1996). One of the great advantages of cross-matching between low- and high-skilled workers is that the low-skilled are offered more opportunities to learn from higher-skilled co-workers. Thus, segregation may deteriorate some of the pre-conditions for economic growth in the long run.

With this background, the findings obtained here are at least to some extent encouraging. It appears that the high-technology plants were able to secure their personnel from unemployment quite effectively also during the recession. More important, we found that the flow of workers from unemployment into high-technology plants was quite substantial in the recovery years. On the other hand, one of the most notable features of the recession was that hiring dried up to one-half (see for example Ilmakunnas and Maliranta, 2000a; 2000b). As a result, the pool of unemployed consisted of an increasing share of young and highly educated persons. When business conditions improved, a large number of high-skilled unemployed was available to high-technology plants. The finding that in 1996 there was hardly any difference in the worker inflow rate from unemployment between low and high R&D intensity plants suggests that the years 1994 and 1995 might have been exceptional in this respect. A more detailed analysis with a breakdown of job creation by skill level would be of utmost importance and would contribute considerably to our understanding of this phenomenon.

This pioneering work on the role of high R&D intensity and technology for job and worker flows at the plant level could be extended also in other ways. It might be useful to include some additional technology indicators to capture the manifold dimensions of high technology. The econometric analysis of net job creation carried out here could be supplemented with an analysis of the relationship between high technology and other flow measures, especially those associated with unemployment and churning. In particular, it might be useful to consider simultaneous determination of churning, R&D effort, productivity and wages with structural models; an exercise for which our data set opens a promising outlook. It would also be important to know to what extent low-skilled individuals benefit from the superior job creation capacity of high R&D intensity plants and firms. All these and many more issues can be studied in-depth with the linked employer-employee data used in this study.

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Appendix of Chapter 4

Table A1. Descriptive statistics of variables used in the regression analysis

Sector and period	Variable	Description of the variable	Nobs.	Mean	Std	Q1	Q3
Manufacturing, 1992							
	NET	Growth of employment	2383	-0.043	0.438	-0.109	0.022
	ln(LP(t-3))	Log of value added per employee	1778	5.446	0.364	5.233	5.605
	RTOT	Total R&D / sales	2383	0.021	0.045	0.002	0.017
	RP	Privately financed R&D/ sales	2383	0.019	0.041	0.002	0.016
	RGOT	Other public R&D / sales	2383	0.000	0.005	0.000	0.000
	RTEK	Tekes financed R&D / sales	2383	0.001	0.004	0.000	0.000
	RDINT	Industry R&D / production	2383	0.017	0.020	0.006	0.031
	IPROS	Process innovation	1167	0.840	0.367	1.000	1.000
	IPROD	Product innovation	1167	0.935	0.247	1.000	1.000
	SMALL	Small firm	2383	0.072	0.258	0.000	0.000
	MEDIUM	Medium-sized firm	2383	0.165	0.371	0.000	0.000
Manufacturing, 1996							
	NET	Growth of employment	3892	0.045	0.323	-0.037	0.089
	ln(LP(t-3))	Log of value added per employee	3237	5.673	0.451	5.400	5.985
	RTOT	Total R&D / sales	3892	0.020	0.038	0.002	0.017
	RP	Privately financed R&D/ sales	3892	0.018	0.035	0.002	0.016
	RGOT	Other public R&D / sales	3892	0.000	0.004	0.000	0.000
	RTEK	Tekes financed R&D / sales	3892	0.001	0.004	0.000	0.000
	RDINT	Industry R&D / production	3892	0.021	0.022	0.005	0.038
	IPROS	Process innovation	1204	0.703	0.457	0.000	1.000
	IPROD	Product innovation	1204	0.824	0.381	1.000	1.000
	SMALL	Small firm	3892	0.092	0.289	0.000	0.000
	MEDIUM	Medium-sized firm	3892	0.216	0.412	0.000	0.000
Services, 1992							
	NET	Growth of employment	8291	-0.086	0.456	-0.160	0.023
	ln(LP(t-3))	Log of value added per employee	1636	5.566	0.427	5.262	5.747
	RTOT	Total R&D / sales	8291	0.019	0.052	0.000	0.009
	RP	Privately financed R&D/ sales	8291	0.018	0.049	0.000	0.009
	RGOT	Other public R&D / sales	8291	0.000	0.005	0.000	0.000
	RTEK	Tekes financed R&D / sales	8291	0.000	0.005	0.000	0.000
	RDINT	Industry R&D / production	8291	0.005	0.005	0.000	0.010
	IPROS	Process innovation	543	0.812	0.391	1.000	1.000
	IPROD	Product innovation	543	0.968	0.175	1.000	1.000
	SMALL	Small firm	8291	0.594	0.491	0.000	1.000
	MEDIUM	Medium-sized firm	8291	0.104	0.306	0.000	0.000
Services, 1996							
	NET	Growth of employment	5849	-0.066	0.467	-0.105	0.092
	ln(LP(t-3))	Log of value added per employee	5368	5.568	0.458	5.126	5.918
	RTOT	Total R&D / sales	5849	0.017	0.047	0.000	0.007
	RP	Privately financed R&D/ sales	5849	0.015	0.041	0.000	0.006
	RGOT	Other public R&D / sales	5849	0.001	0.006	0.000	0.000
	RTEK	Tekes financed R&D / sales	5849	0.001	0.007	0.000	0.000
	RDINT	Industry R&D / production	5849	0.010	0.013	0.001	0.029
	IPROS	Process innovation	762	0.189	0.392	0.000	0.000
	IPROD	Product innovation	762	0.844	0.363	1.000	1.000
	SMALL	Small firm	5849	0.082	0.274	0.000	0.000
	MEDIUM	Medium-sized firm	5849	0.150	0.357	0.000	0.000

Notes: Nobs. refers to the number of plants. Mean, standard deviation (std), first quartile (Q1), and third quartile (Q3) are employment weighted.

Appendix I

R&D SUPPORT AND THE PERFORMANCE OF FIRMS: A LITERATURE REVIEW

Synnöve Vuori

Acknowledgements: This chapter is edited from a text finalised by Synnöve Vuori before she left ETLA in November 1999. Additional literature is surveyed in Chapters 3 and 4 of this volume. (Editor's comment)

1 Introduction

Evaluations of the impacts of public R&D support on the performance of firms have grown rapidly in number over recent years. This is true for Finland similarly as for other countries. Both qualitative and quantitative methods have been used in the evaluations made so far. For example, peer reviews have been widely used in evaluations of technology support. Another frequently used approach is case studies, which may provide important and deep insight into the mechanisms and factors affecting the innovation process. However, in general they concern only a limited number of firms and may thus suffer from not being representative. Econometric studies may, according to the availability of data, cover a large number of firms or industries, and take the various factors affecting performance more systematically into account. However, causality between the factors analysed may be difficult to establish.[1]

Evaluations have been carried out in different stages of R&D projects: ex-ante, ongoing, and ex-post evaluations can be distinguished. Quite often, the primary goal has been to assess the attainment of technological goals for the projects, whereas the economic impacts have received less attention. More recently, however, the socio-economic impacts are seen as an increasingly important part of an overall evaluation of the success of public R&D funding. Regarding the economic effects of public support to business R&D, Capron et al. (1997) distinguish between four different objectives to be included in the evaluation, all complementary to each other: (1) the stimulus effect (quantitative and qualitative effects on firms' R&D activities); (2) the productivity effect (impact on the economic performance of firms); (3) the spillover effect (impact on the economic performance of industries); and (4) the global effect (impact on the economy as a whole).

In this chapter, a few examples of results from previous studies are briefly reviewed. Without in any way aiming at comprehensiveness, this short review seeks to describe widely used approaches and some results so far obtained in evaluations of public R&D funding.

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1 For a review of evaluation methods, their relevance and drawbacks, see Capron et al. (1997, especially Table 1 on p. 37).

2 International evidence

According to the OECD (1998), direct financial support to R&D has generally been found to have a modest but positive effect on total business R&D expenditure, with corresponding social benefits in terms of additional growth in productivity and wealth. On the basis of some programme-level evaluations, public support seems to enlarge the scale and quicken the pace of R&D, but seldom re-orients existing research themes of recipient firms. There also seems to be some trade-off between increasing additionality (implying that more is done instead of just replacing private funds with public funds) and ensuring greater economic impacts.

Mamuneas and Nadiri (1996) evaluate the contributions of tax incentives and public financing of R&D investment policies in promoting the growth of output and productivity of US manufacturing industries. They estimate a cost function dual to a production function where, in addition to the prices of the traditional inputs, the rental price of company-financed R&D capital, and the capital stock of publicly financed R&D, explicitly enter into the cost function. The cost function is based on a standard neo-classical production function, augmented with three different R&D capital stocks. In addition to the R&D financed by the industry, they consider two types of publicly financed R&D, of which one is performed within the industry and the other outside it. This allows the consideration of possible spillover effects from publicly financed R&D.

According to Mamuneas and Nadiri (1996, pp. 77–78), "…publicly financed R&D and company-financed R&D are substitutes in low R&D intensive industries, but are weak substitutes in high R&D intensive industries. Thus, an increase in publicly financed R&D capital increases the efficiency, in terms of unit cost savings, of the industries in the manufacturing sector, but crowds out privately financed R&D investment." Further, "…publicly financed R&D investment is a more appropriate tool for increasing efficiency and possibly for stimulating output growth, while the R&D tax policy is a more appropriate tool for stimulating the private sector's R&D investment. Therefore, both instruments – subsidies and direct financing or publicly financed R&D expenditures – are important elements for sustaining output growth and productivity increase in the manufacturing sector."

Bergström (1998) analyses, using Swedish firm and industry data, the effects of public capital subsidies on productivity growth and employment creation. The approach is very similar to those used in several other studies concerning the effects of R&D subsidies. The focus is on regional policy and selective subsidies, that is, subsidies that are allocated to firms on the basis of certain criteria (in contrast to general subsidies, which are granted to all firms). Firstly, the effects on total factor productivity (TFP) of capital subsidies used in Sweden are analysed. The data set consists of Swedish subsidised and non-subsidised firms in the period 1987–1993. TFP growth in supported and non-supported firms is compared using a production function approach. Controlling for different factors that may affect productivity, the study examines whether there are any differences in productivity performance between the firms in the years after the subsidies were granted.

In the estimated statistical model, growth in value added was explained by growth in the capital stock and the number of employees, the age of the firm, a dummy variable defined on the basis of location within the support areas vs. outside them, the total value of subsidies received divided by the number of employees, and industry dummies. To examine if the effects of the subsidies change over time, the model was re-estimated for four periods: 1989–90, 1989–91, 1989–92, and 1989–93. In addition, data for 1987 and 1988 were used to examine the historical performance of the firms. Before estimating this equation, a logit model was used for examining whether different firm characteristics can be used to discriminate between the two types of firms.

According to the results, the subsidised firms seemed to a larger extent to be located within the support areas, to be younger and also to be less labour-productive than the non-subsidised firms. In the period 1987 to 1989, that is, before the subsidies were granted, the two groups of firms seemed to have performed equally well. Subsidisation was positively correlated with growth of value added, and productivity of the subsidised firms increased the first year after the subsidies were granted. However, after the first year, TFP seemed to develop more weakly, the more subsidies a firm had been granted. According to the author, this may imply that less productive firms have been subsidised, and in addition, subsidisation may also make firms less efficient.

Next the employment effects of capital subsidies in Sweden were examined. In this analysis, only firms located within the support areas were studied. To test whether the capital subsidies affected the total level of employment between 1988 and 1993, the supported and non-supported firms were examined at an aggregate level in order to cancel out firm-specific factors. The dependent variable was an index of the development of total employment of supported and non-supported firms in two-digit level industries between 1988 and 1993. The general development of employment in the whole industry, a few control variables and a time dummy for the supported industries for each year between 1988 and 1993 were included in the model. The control variables are thought to pick up firm-specific factors. These include capital intensity (total assets per employee), size (average turnover), productivity (value added per employee), skill level (proxied by average wages), age (average year firms were founded), and profit (value added minus wages, divided by total assets).

According to the results, capital subsidies do not seem to affect total employment of supported firms. Instead, both supported and non-supported firms follow the general economic development. In addition, industries which consist of larger firms and firms that pay out higher wages have a higher employment level, that is, employment did not fall as much in these industries as it did in the other ones in the period studied. The other variables were insignificant.

Klette and Møen (1999) focus on information technologies as an example of generic or general purpose technologies (GPTs) and the role of public policy in co-ordinating the introduction of GPTs. According to Bresnahan and Trajtenberg (1995), at any point in time there are a handful of general purpose technologies (GPTs), characterized by the potential for pervasive use in a wide range of sectors and by their technological dynamism. GPTs have an inherent potential for technical improvements and involve innovational complementarities, giving rise to increasing returns to scale. Innovational complementarities imply that the productivity of R&D in a downstream sector increases as a consequence of innovation in the GPT technology. The complementarities increase the effects of innovation in the GPT, and facilitate their diffusion throughout the economy. Most GPTs play the role of 'enabling technologies', opening up new opportunities rather than offering complete, final solutions.

There are two main externalities associated with the GPTs. The first one is vertical and links the payoffs of the inventors in the GPT and in the application sector. It is a consequence of innovational complementarities. This situation involves a bilateral moral hazard problem, where the incentives to innovate may be too low in both sectors. The second externality is a horizontal one and concerns the innovators in the various application sectors. Here also the incentives to innovate may be too low. The complementarities involved create pecuniary externalities and a need to co-ordinate the innovation activities of these sectors, a task for technology policy (see Bresnahan and Trajtenberg, 1995, and Klette and Møen, 1999).

Klette and Møen (1999) analyse a series of IT programmes implemented in Norway from the early 1980s onwards and their economic results. The economic effects of R&D support within the Norwegian IT programmes are analysed in three different ways. The authors compare the performance of firms receiving support to other firms in the same industry. They also compare the performance of the supported industries to the rest of the manufacturing sector, and the performance of high-tech industries in Norway to their performance in other OECD countries.

Klette and Møen (1999) first compare subsidised and non-subsidised firms to clarify whether subsidised firms on average have performed better than the others. They use a dummy variable approach and eight alternative performance measures. Their R&D subsidy dummies are based on the share of subsidies in total R&D over the three years preceding the year of observation. One of the dummies indicates a subsidy share between 5 and 25 per cent, and the second dummy a subsidy share above 25 per cent. A subsidy of less than 5 per cent is not expected to have much effect on performance. Each performance measure was regressed on the two subsidy dummies as well as time and industry dummies. An additional dummy variable concerned performing R&D; this variable obtained the value of one if the firm had reported R&D in at least one of the three years preceding the year of observation. The authors note that significant coefficients may be due also to reversed causality, or to a situation where successful (or unsuccessful) firms have a higher probability of receiving subsidies. In order to at least partly control for this, they repeat the estimations using plant-specific fixed effects, which is equivalent to measuring all variables as deviations from the firm-specific means.

The performance measures analysed are growth in man-hours, growth in sales, return on assets, profit margin, labour productivity, total factor productivity, investment intensity, and intensity of privately financed R&D. According to the regression results, there do not appear to be important differences between subsidised and non-subsidised firms as to firm growth, measured either by growth in man-hours or sales. The same applies to profitability: neither returns to assets nor profit margins seem to differ significantly between the two types of firms. However, a general characteristic of all R&D performing firms was that they had higher profit margins than firms without R&D.

Productivity was measured by both labour productivity and total factor productivity. It turned out that the subsidised firms had a lower level of productivity, and the differences were statistically highly significant when fixed effects were included. Investment intensity was measured by investments in machinery and buildings relative to sales, which was used as a proxy for expected growth in sales. According to the estimation results, again there were no systematic differences between subsidised and non-subsidised firms. Privately financed R&D was taken to proxy for previous R&D success, in addition to being a focus of interest in itself as an explicit aim of the technology programmes. However, Klette and Møen (1999) found no significant differences between the intensity of privately financed R&D in subsidised and non-subsidised firms.

Secondly, they compared the growth of subsidised and non-subsidised firms that existed in 1985, over the entire decade 1985 to 1995. Subsidised firms had a higher R&D intensity than non-subsidised firms, but the subsidies did not seem to have stimulated R&D investment. In terms of growth in the number of employees or in sales, non-subsidised firms had performed better. The differences in labour productivity were not large between the two groups of firms. Non-subsidised firms were more profitable, but subsidised firms had stronger growth in profitability.

Thirdly, Klette and Møen (1999) compared the performance of Norwegian high-tech industries to the total Norwegian manufacturing sector and to the IT industries in other OECD countries. Despite the fact that IT and other high-tech industries in Norway have a smaller share in total manufacturing than the OECD average, Norway has conducted a larger share than the OECD average of its total manufacturing R&D within these industries. The R&D intensity in the Norwegian IT industry is also very high internationally. A summary conclusion of the analysis of the economic effects of the Norwegian R&D subsidies to the IT industry is that the public financial support to R&D and innovation did not create a substantial stimulus to its performance.

The methodology and set-up of empirical studies evaluating the effects of public R&D funding involve several problems. Many of these are related to selectivity issues. For example, Klette et al. (2000) note in a critical study that neither firms receiving support, nor those not applying, are random samples. In addition, the non-supported firms may also benefit from spillovers originating in the supported programmes, which should be taken into account when comparing the supported and non-supported firms. Klette et al. (2000) also discuss the issues involved in constructing valid control groups in these kinds of research approaches.

Looking more broadly at the examples described above from studies concerning the effects of public (R&D or capital) support, it is evident that there is no guarantee at all that the goals aimed at with the support are attained. Moreover, the scope and interrelatedness of the factors involved in the performance of firms are so complex that identifying the effects of public support to firms is indeed a challenging task.

3 Empirical evidence for Finland

In Finland technology and innovation policy evaluations have been carried out since the early 1980s. The first evaluations were mostly quality evaluations of basic and mission-oriented research, and used panels of external experts. In the early 1990s evaluations concerned largely research organisations, research institutes and research funding agencies (for example, the Academy of Finland, The National Technology Agency (Tekes), the Technical Research Centre of Finland (VTT) and the National Health Institute). These evaluations focused on to what extent these organisations had fulfilled their missions. Towards the end of the 1990s, evaluations became normal practice. All important public programmes involving R&D funding and concerning the development of research infrastructures were made subject to evaluations (Luukkonen, 1997). A large part of the evaluations performed so far has focused on the scientific quality and achievement of technological goals of the research and financing organisations and have used peer review methods. So far there has been very little analysis of the economic effects of publicly funded research activities (OECD, 1998).[2]

One of the earliest studies is an analysis of the success of R&D projects financed by the Finnish National Fund for Research and Development (Sitra) since its start, covering the period 1968 to 1985 (Carlson, 1987). A total of 452 completed product development projects were examined. In general terms, half of the projects were assessed to have been successful and the other half had failed. No special characteristics could be distinguished on the basis of which good projects could have been selected in advance. Success was slightly more probable in smaller firms where the project was controlled by top management, for projects which were carefully prepared and where the novelty degree was not too high, and for firms in the engineering industry.

As part of an international evaluation of Tekes, a study evaluating Tekes funding for industrial R&D was published in 1995 (Numminen and Hämäläinen, 1995). A follow-up study used partly the same material

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2 For more details on the development of evaluation practices concerning mission-oriented research in Finland, see Luukkonen (1997).

(Numminen and Hämäläinen, 1997). Both studies surveyed 601 industrial R&D projects that had received funding from Tekes and had been completed between 1990 and 1993. In the first study, the projects were assessed to be in general very successful in terms of new products, immediate economic effects, as well as indirect and broader effects. However, the positive results must be seen in the light of their being completed projects; projects which had not started despite a funding decision by Tekes and projects which had been interrupted were not included in the survey.

Two-thirds of the completed projects were reported to have been important or moderately important to the business strategy and to the technology strategy of the firm. Additionality of Tekes funding was found to be reasonably high. One-fourth of the respondents estimated that the project would not have been done without the funding. Two-thirds reported that without the funding, the projects would have been done in a different way (on a smaller scale, with more modest objectives, within a longer period, etc.).

The second study (Numminen and Hämäläinen, 1997) first examines the factors affecting the success of product development projects from the firm's viewpoint. According to the results, firm size, the strategic importance of the project to the firm, and vertical Cupertino had influenced the success of the R&D projects. Secondly, the study analyses the success of the projects from the point of view of public funding in terms of additionality and the significance of the support for the projects and firms involved. Additionality seemed to be primarily linked to changes in the firm's behaviour in carrying out the project. Public funding seemed to promote collaboration and interaction between the various actors of the innovation system. Thirdly, a group of interrupted projects was analysed. The most usual reasons for the interruption of the project were related to the commercialisation of the research results, lack of financing or human resources, or changes in the firm's strategy or organisation. Small firms interrupted their projects more frequently than larger ones.

An evaluation of the promotion of independent inventions and their commercialisation in Finland (Zegveld et al., 1998) concluded, among other things, that there should be a better balance between R&D and the promotion of inventiveness/innovation. There should also be more coherence between the organisations involved in the promotion activities.

Niininen (1996, 1997) has analysed, among other things, the determinants of R&D investment. Niininen (1999) also includes analyses of the effects of privately and publicly financed R&D. At the industry level, both types of R&D were found to have had a considerable effect on the growth rate in total factor productivity in the period 1975 to 1993. However, total R&D accounted for only about 8 per cent of TFP growth. At the firm level in the period 1985 to 1993, public R&D subsidies had a significant but limited effect on the firms' total R&D investments, affecting mainly firms with high R&D intensity. Subsidised loans seemed to induce additional R&D investment more effectively than direct subsidies. Subsidised loans also appeared to have a positive effect on labour productivity.

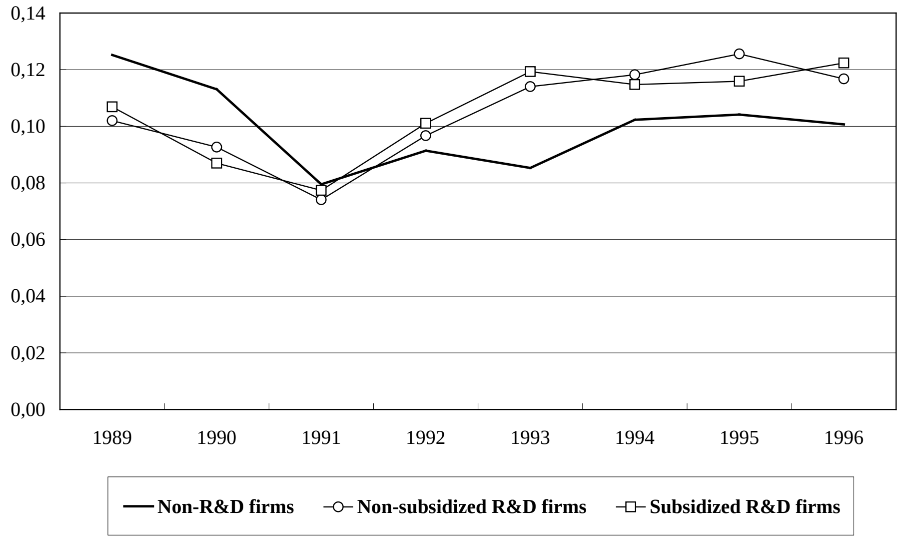
Ali-Yrkkö (1998) examines the determinants of the fixed investments and R&D investments of Finnish manufacturing firms. Profitability was found to be an important determinant of R&D investments. The impact of public R&D funding was also analysed. For financially constrained firms with a low ability to pay interest expenses, public R&D funding increased their R&D expenditures more than for other firms. However, public funding did not increase the R&D expenditures of small firms more than in large firms.

A preliminary study using a broad set of plant- and firm-level data describes the dynamics of firm productivity and profitability from 1985 to 1996 (for more details, see Lehtoranta, 1999). Among other things, the data analysis involved a comparison of profitability, measured as the operating profit ratio (OPR), in three groups of firms. These were firms that did not perform R&D, R&D-performing non-subsidised firms and R&D-performing subsidised firms. When linking the OPR medians from three different panel data sets, the development within the three firm groups has evolved as shown in *Figure 1*.

The firms which did not perform R&D had the highest median operating profit ratio in the beginning of the period studied (1989), but their relative position deteriorated towards the end of the period. The profitability of R&D firms increased rapidly after 1991, but with a somewhat different pattern for subsidised and non-subsidised firms. The growth in profitability of subsidised firms levelled off in 1994 and 1995 but started again in 1996. In non-subsidised R&D firms, on the other hand, growth continued until 1995, but there was a decrease in 1996. The differences in the performance of subsidised and non-subsidised firms could partly be related to differences in size and industry breakdown in the groups. The period studied contains an exceptionally severe recession and a rapid recovery, which should also be taken into account when assessing the results.

In a subsequent study Lehtoranta (2000) analyses mainly the effects of direct subsidies and subsidised loans provided by the National Technology Agency (Tekes) on firm profitability and sales trends. According to the

Figure 1. Profitability (operating profit ratio) in subsidised and non-subsidised R&D firms and in non-R&D firms



Source: *Lehtoranta (1999)*

results based on a fixed effects model using a panel of 748 firms in the period 1991–97, firm sales were significantly influenced by the number of employees, the proportion of staff with a researcher and academic education, the share of exports, innovativeness, capital and R&D intensity, and to some extent by foreign ownership. Firm profitability (operating margin as a proportion of turnover) was influenced by the industry of the firm and by the firm's capital intensity, but not by its innovativeness, R&D intensity or public R&D support. In contrast, direct subsidies and subsidised loans had a minor but statistically highly significant positive effect on the number of employees.

To sum up, so far we have only scattered evidence of the effects of public R&D funding on the economic performance of Finnish firms and on the development of their R&D investments. In particular, there are only a few econometric analyses. Survey-based studies have provided varying results. According to the results of Carlson (1987), only half of the subsidised R&D projects analysed were successful. In later studies subsidised projects were assessed to be mostly successful in producing new products, economic results and additional R&D (Numminen and Hämäläinen, 1995, 1997). The econometric results of Niininen (1996, 1997, 1999) also suggest that R&D subsidies have induced additional R&D investments.

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Appendix II

JOBS AND TECHNOLOGY: SOME FINNISH EVIDENCE

Antton Lounasheimo

Acknowledgement: Helpful comments are due to Rita Asplund, Mika Maliranta and Pekka Ylä-Anttila.

1 Are the new jobs created in high-tech industries only?

It is conventional wisdom that technological progress both creates and destroys jobs. It is, therefore, of considerable importance to gain knowledge on the net effect of this process in the long run. With technological progress the structures of economies and the demand for labour change their nature. Some (new) high-tech industries may suffer from a severe shortage of employees at the same time as people are laid off in other industries that rely on older technologies. This may lead to serious imbalances in the labour market. Indeed, according to a recent study by Pehkonen (1998), this imbalance worsened in Finland during the recessionary period of 1990–1995, when there was a huge increase in the sectoral mismatch between vacant jobs and job seekers.[1]

In all industrialised nations there has been a transition in the allocation of labour from agricultural to industrial and service sectors during the last couple of centuries. Over the last few decades industrial employment has also been decreasing and employment growth in services has accelerated. It is often claimed that one key explanation for this restructuring is that technological advance has affected agriculture and manufacturing more than the service sector (Laaksonen, 1999).[2] High-tech manufacturing industries have nevertheless experienced a favourable employment development over the past few decades, and especially when compared to other manufacturing industries (*Figure 1*), but it has also been more volatile with a faster job decline between 1990 and 1994 than in other sectors (OECD, 1998, p. 49). Figure 1 shows that the employment development in non-high-tech manufacturing industries has mostly been negative since 1980. Despite the decline between 1990–1994, employment in high-tech industries is on a higher level than in 1980 and the trend points upward.

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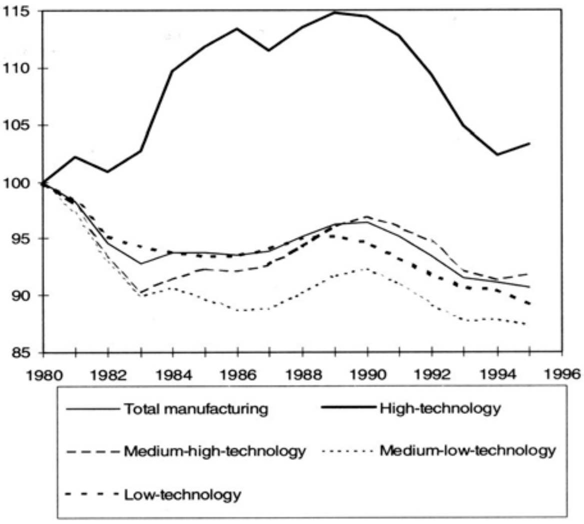
1 See also Figure A1 in the Appendix, which shows the shortage of skilled labour in Finnish industry in the 1990s.

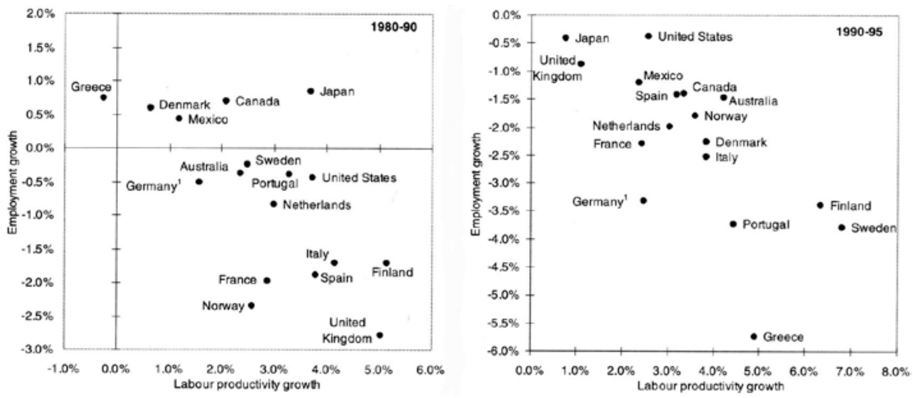
2 There are also other explanations for this transition, such as the fact that the demand for services has grown more rapidly than for industrial or agricultural products and that industrial companies have increasingly been outsourcing non-essential tasks to service sector firms (see Laaksonen, 1999, p. 26).

Figure 1. Employment trends in manufacturing by technological level, total OECD, 1980=100



Source: *OECD (1998)*

Figure 2. Productivity and employment growth in manufacturing. Average annual growth rates between indicated years.



Source: *OECD (1998)*

Figure 2 shows that an overall decline in manufacturing employment has occurred in most of the OECD countries at the same time as labour productivity has increased, caused by technological advance

(OECD, 1998). We can observe that Finnish manufacturing has had one of the fastest productivity growth and employment decrease rates in the OECD.

According to a study of Finnish manufacturing establishments for the years 1987–1993 (Laaksonen and Vainiomäki, 1997), the high-tech industries were characterised by both higher job creation and job destruction rates than the other industries, and consequently also by a higher gross re-allocation of labour (simultaneous job creation and destruction). The more advanced technology industries also had a more positive development in terms of net employment.[3] High annual rates of job destruction combined with low rates of job creation gave the low-tech industries the poorest employment performance. *Table 1* shows some of the results reported by Laaksonen and Vainiomäki (1997).

Table 1. Job re-allocation (annual) rates by technology level in Finnish manufacturing plants for the years 1987–1993

	Job creation rate	**Job destruction rate**	**Net empl. growth**
Technology level			
high	10.6	13.0	-2.3
medium-high	6.7	10.6	-3.9
medium-low	6.1	9.7	-3.6
low	5.6	12.4	-6.8

Source: *Laaksonen and Vainiomäki (1997)*

Table 2 presents results from another study showing (gross) employment changes in Finnish manufacturing according to the technology level of industries in the period 1987–1995 (Parjanne, 1999).

Finland's deep recession in the early 1990s has left its mark on the numbers in Tables 1 and 2. Again, we can observe wide fluctuations in the employment numbers of the high-tech segment. As a whole, however, the low technology industries have seen the poorest employment development: their employment record has persistently

3 These Finnish results are therefore in line with the evidence for the whole OECD area depicted in Figure 1, with the best employment development and high rates of both job creation and destruction in high-tech manufacturing.

been negative. In the high technology industries employment started to grow already in 1992, in the middle of the recession.

Table 2. Changes in employment in Finnish manufacturing

	Technology level by industry		
	high	**middle**	**low**
Number of employed in 1995	124 000	84 000	205 900
Change in employment, %			
1987–1989	-0.9	23.2	-0.4
1989–1991	-28.1	-22.8	-18.9
1991–1993	1.4	-29.8	-8.4
1993–1995	24.1	39.6	-0.6
1987–1995	-10.3	-6.8	-29.1

Note: The categorisation of industry branches into technology levels follows the OECD definition.
Source: *Parjanne (1999)*

2 Growing demand for high-skilled labour

Along with technological progress, the demand for high-skilled workers grows while the demand for low-skilled workers shrinks. The demand for the high-skilled starts in high-tech companies but spreads with time to other sectors of the economy. Globalisation of trade relations is also considered to contribute to the rising demand for high-skilled labour. Development of products sold in world markets requires research and development investments that often lead to a technological change, further reducing the need for low-skilled workers. Indeed, globalisation and international competition seem to accelerate technological change (Parjanne, 1999). A further threat against the low-skilled originates in direct foreign investments and the integration of international information and communication systems, both of which spread knowledge and new innovations rapidly from country to country (Ylä-Anttila, 1999). The effects of international technological spillovers increase the demand for qualified labour especially in heavily export-oriented industries and economies.

The development of the relative shares of high- and low-skilled workers is often used to depict the biased impact of technological change on labour demand. *Table 3* shows how the proportions of blue- and white-collar workers have been evolving in Finland in the years 1987–1995, first in the manufacturing sector and then in the whole Finnish economy.

Table 3. Shares of blue- and white-collar workers in the Finnish economy

	1987	1989	1991	1993	1995
Manufacturing:					
Blue-collar, %	72.0	68.5	64.4	63.7	63.5
White-collar, %	28.0	31.5	35.6	36.3	36.5
All sectors:					
Blue-collar, %	44.9	44.2	41.4	39.1	39.5
White-collar, %	55.1	55.8	58.6	60.9	60.5

Source: *Parjanne (1999)*

From the table it is evident that the Finnish economy is undergoing a fast-moving structural change. The proportion of blue-collar workers has decreased rapidly, a change that was further accelerated by the recession of the early 1990s. This scenario is problematic for the future prospects of low-skilled workers as the demand for higher skills characterises all industries and not only the high-tech ones. Further education and training of low-skilled workers is seen as a key solution for improving their possibilities of remaining employed (Jackman et al., 1996; Parjanne, 1999).[4]

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4 However, because of the rise in the educational level of younger generations new fears have been arising about the possible future lack of low-skilled workers in Finland. There may not be enough workers to fill low-skilled jobs when the baby-boomers of the 1940s have retired.

3 Industry-level dynamics

The Finnish banking and finance sector was regulated and protected from foreign competition until the mid-1980s. For instance, there was no actual interest rate competition between different banks before that. The sector has experienced a huge re-structuring since then, which has resulted in a significant number of job losses. The sector is nowadays highly competitive and new banking technologies have been introduced rapidly during the last two decades. They have also had an effect on the employment situation of the sector (Hernesniemi, 1999). *Table 4* below shows the rapid decline in the number of bank branches and employees combined with different steps of the technological progress.

Table 4. The evolution of banking in Finland

	1980	1985	1990	1995	1997
automatic teller machines	123	703	2838	2421	2285
withdrawals, mill.	-	22	119	201	223
bank transfer machines,	0	0	505	2153	2482
transfers, mill.	0	0	2	56	68
electronic access to banks					
(e.g. from home), 1000 units	-	9	126	761	1452
payment transfers, mill.	-	121	491	611	670
electronic payment terminals					
in retail stores	-	40	26500	49000	54000
transactions, mill.	-	1	83	144	178
bank branches	3378	3566	3301	1953	1644
staff in banking and finance	42447	46923	50500	32128	26717

Source: *Hernesniemi (1999)*

Hernesniemi (1997) has studied in-depth the relationship between production and employment in different Finnish industries from 1980 to 1996. The industries were classified into seven categories: Declining industries, Stagnating industries, Jobless growth industries, Booming industries, Cyclical growth and rationalisation waves industries, Industries under market transformation and Industries growing by political decision. The following table gives the employment development (in 1,000 persons) of these categories between 1980 and 1996.

Table 5. Employment development by industry category (in 1,000 persons)

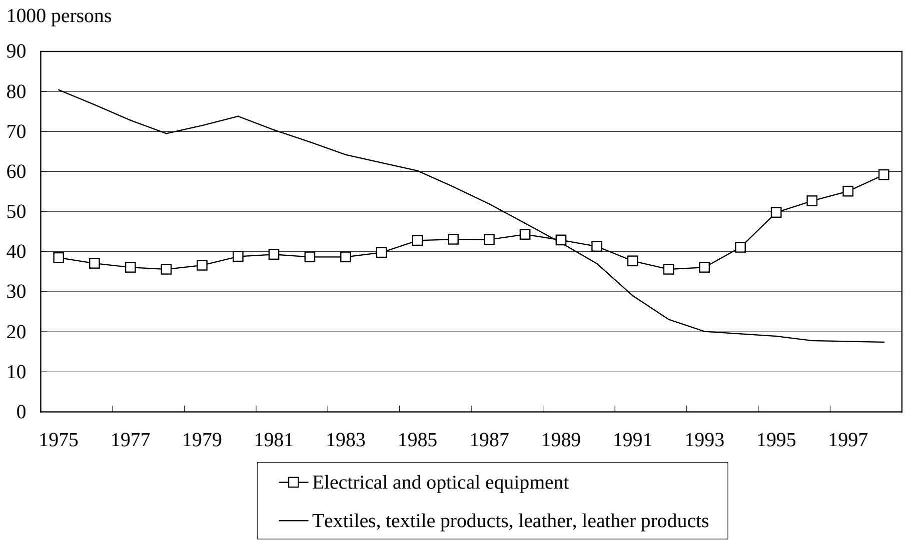
Industry	1980	1990	1996	Total change 1980–1996
Declining industries	247,8	235,5	139,3	-108,5
Stagnating industries	467,3	338,3	247,8	-219,5
Jobless growth industries	181,1	155,4	126,4	-54,7
Cyclical growth and rationalisation waves industries	132,2	128,0	116,2	-16,0
Booming industries	209,4	293,5	306,3	+96,9
Industries growing by political decision	383,3	491,6	475,1	+91,8
Industries under market transformation	635,4	708,7	555,8	-79,6

Source: *Hernesniemi (1997)*

As the numbers show, only two industry groups had a positive employment development during the period. The booming industries category includes the following industries: manufacturing of electrical and optical equipment, insurance, services for financial and insurance industries, real estate, business services and finally other services. The other group showing a positive employment growth is industries growing by political decision.

Figure 3 shows employment trends for two Finnish industries having had very different employment records. The first one, manufacturing of electrical and optical equipment, is a typical high-tech industry and belongs to the booming industries group. Here is, again, an example of high-technology manufacturing having experienced a positive employment development. However, many services also belong to the category of booming industries. The other one, manufacturing of textile and leather products, can be considered a typical low-tech sector and belongs to the declining industries category in Table 5.

Figure 3. Employment (in 1,000 persons) in two Finnish manufacturing industries



Source: *Etla's database*

It is commonly known that new technologies and increased productivity are the force behind increases in wages and incomes. Higher incomes, on the other hand, increase the demand for services. According to a recent OECD study, this is an indirect positive employment effect of technological progress (OECD, 1998). When these conclusions are applied to the Finnish case it seems likely that also the good employment development in services is boosted by higher incomes created by technological advancements and increased productivity. However, clear Finnish research results are missing on this point.

4 Jobless growth

From 1990 to 1993 the unemployment rate in Finland rose dramatically, from 3.5% to 18%.[5] When the economy started to grow again in 1993, unemployment was still on the rise and stayed at a high level

5 This was due to many reasons: a persistent current account deficit, a high level of foreign debt, the international economic recession, the collapse of trade with the Soviet Union, structural problems in the economy, etc. (see Kiander and Vartia, 1998).

through the entire decade, despite high annual GDP growth rates (around 4% annually since 1994). This led to a hectic discussion about the effects of technology and "jobless growth" in Finland. Among the questions raised were (and are) the following: Did the economic recession of the early 1990s change the way the Finnish labour market operates (Pehkonen, 2000)? What are the effects of technological progress on labour demand?

Sauramo (1999) discusses the main interpretations of the exceptional unemployment development in Finland in the 1990s. He tries to explain why employment growth was so low during the whole decade. Is it an enhanced productivity growth that has caused jobless economic growth, or is it just that the growth in the economy has not been strong enough to create new jobs? Labour productivity in Finland grew very rapidly during the period 1992–1994, i.e. in the middle of the recession, and exceeded substantially the average long-term trend growth rate. After 1994 the productivity growth rate has been in line with the average long-term growth rate, but the productivity *level* has stayed above the trend level.

Sauramo seeks for an explanation by analysing how technological and demand shocks have affected productivity, output and employment. He finds that a positive technology shock increases productivity both in the short and in the long run. Its effect on output is more or less obscure and it decreases employment, at least in the short run. An aggregate demand shock, on the other hand, increases output and employment both in the short and in the long run. It also has a positive effect on productivity, but only in the short run.

Sauramo uses these results in an attempt to explain the Finnish unemployment dilemma of the 1990s. He finds that in the beginning of the recession the strong decline in productivity growth was caused by a huge negative aggregate demand shock, which also resulted in rapidly worsening employment. Technology shocks did not play a significant role here. However, when productivity started to grow again in 1992, this was caused by positive technology shocks. These technology shocks also affected employment. In particular they caused a further reduction in employment, and in 1993–1994 they reduced employment more than the aggregate demand shocks did. According to Sauramo, the years 1992–1994 were characterised by "jobless growth" in Finland. After 1994 the situation has normalised and no new "era of jobless growth" has begun.

Sauramo futher argues that the technology shocks of his model do not have to be purely associated with real technological progress. Changes in the structure of industries as well as changes within industries, at the plant level, may equally well cause a jump in average labour productivity (Sauramo, 1999). He then refers to Maliranta (1997) who has studied the effects of micro-level structural changes on aggregate productivity in Finnish manufacturing. Maliranta finds that changes in the structure of manufacturing units of business increased the growth rate of labour productivity since the late 1980s and especially in the years 1993 and 1994. Over this time period a substantial number of low-productivity plants vanished and there was a flow of workers from low-productivity to high-productivity units of business. In other words, there was "creative destruction" in the structures of business. The technology shocks studied by Sauramo also depict this change in the structure of Finnish business and the consequent re-allocation of labour and not merely pure rapid technological progress at the plant level.

According to this view, the exceptionally rapid growth in labour productivity in the middle of the recession, the upward shift of the productivity level since the end of the recession and the high unemployment rate during the 1990s are all symptoms of an ongoing structural change in the Finnish economy that is removing inefficient structures developed before the recession. Sauramo futher argues that apart from inefficient structures, the exceptionally bad economic situation also prompted the structural alteration.

5 Conclusions

Employment in Finnish manufacturing has decreased while, at the same time, productivity has increased. Only high-tech manufacturing industries like manufacturing of electrical and optical equipment have had a positive employment development during the last two decades.

Productivity increases due to technological progress, but also to the removal of inefficient structures in the economy. It is widely held that a higher productivity level increases wages and incomes in the economy, which in turn raises the demand for services. Many service industries have, indeed, belonged to the booming industries in Finland and their employment growth has been positive.

The demand for low-skilled workers decreases along with technological evolution. The new jobs that are created in the service sector and in high-tech manufacturing firms increasingly require high-skilled labour. This is evident in the rapid decrease in the share of blue-collar workers in the Finnish economy. Further education of the less skilled is seen as a key solution for improving their employment situation.

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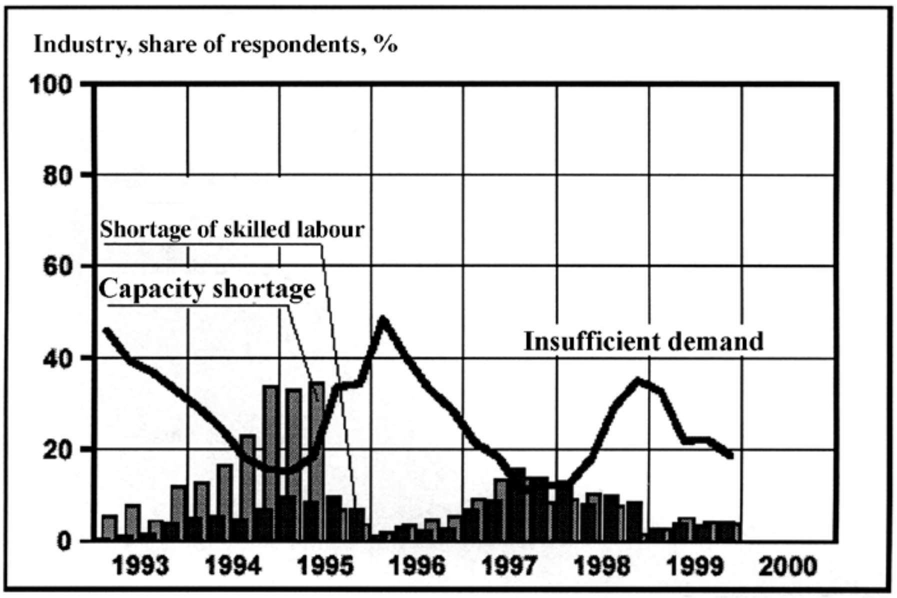
Appendix

Figure A1. Production bottlenecks in Finnish industry



Note: The figures indicate the percentage of the Confederation of Finnish Industry and Employers' (TT) member companies suffering from a lack of skilled workers and cover most industries. There have obviously been times in the 1990s when Finnish companies have distinctly suffered from the lack of skilled labour.

Source: *The Confederation of Finnish Industry and Employers' (TT) homepage 29.3.2000. http://ww.tt.fi/*

SUOMENKIELINEN YHTEENVETO[1]

(Käännetty luvusta 1 Introductory summary)

[1] Tekstissä mainittu kirjallisuus on lueteltu luvun 1 lopussa.

Investoinnit aineettomaan varallisuuteen muodostavat ratkaisevan tärkeän tukipilarin nykypäivän tietointensiivisissä talouksissa. Yritykset panostavat huomattavasti kilpailukykynsä inhimillisiin voimavaroihin ja lisääntyvässä määrin myös teknologisiin innovaatioihin. Menestyksekkäät innovaatiot eivät kuitenkaan riipu ainoastaan yrityksen aineettoman varallisuuden määrästä ja laadusta; yhtä tärkeitä ovat yritykseen kertyneiden taitojen ja luovuuden tehokas hyväksikäyttö ja jatkuva uusien tietojen saanti ulkoisvaikutusten ja muiden yritysten ja tutkimuslaitosten kanssa tehtävän yhteistyön kautta.

Suomi sijoittuu kärkeen yhdessä muiden Pohjoismaiden ja Ranskan kanssa tuoreessa OECD:n tietoinvestointivertailussa, jossa tietoinvestoinnit määritellään tutkimus- ja kehityskulujen, julkisten koulutusmenojen ja ohjelmistoinvestointien summana (OECD, 1999). Tämän aseman saavuttamiseen on johtanut OECD-alueen ajanjaksolla 1985–1995 korkein kyseisten investointien keskimääräinen vuosittainen kasvuvauhti (3,9 %). Samanaikaisesti nopea panostusten kasvu tiedon tuottamiseen on tehnyt tietoinvestoinneista jopa kone- ja laiteinvestointejakin tärkeämpiä.[2] Suomalaiset yritykset ovat pyrkimyksissään varautua globalisaation haasteeseen hyötyneet omien aineettomien varallisuuksiensa lisäksi suuresti ulkoisvaikutuksista ja yhä enenevässä määrin myös eri yhteistyöjärjestelyistä.[3] International Institute for Management Development (IMD) onkin muutamana viime vuotena arvioinut Suomen maailman johtavaksi maaksi sekä yritysten välisen teknologiayhteistyön että yritysten ja yliopistojen välisen tutkimusyhteistyön saralla.

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2 Suomen vuoden 1995 lukujen mukaan tietoinvestoinnit olivat 9,5 %:a BKT:sta, kone- ja laiteinvestointien ollessa 7,0 %:a ja muiden aineellisten investointien 9,2 %:a (OECD, 1999, [Annex] taulukko 2.1.1). Tärkein osatekijä tietoinvestoinneissa on julkinen koulutustuki 6,2 %:n osuudella BKT:sta. Tutkimus- ja kehitysmenot kattavat 2,1 %:a ja ohjelmistoinvestoinnit 1,2 %:a BKT:sta.

3 Empiiristä näyttöä, joka todistaa ulkoisvaikutusten myönteiset efektit suomalaisten teollisuudenalojen ja yritysten teknologiselle kehitykselle, on olemassa suuret määrät, katso esim. Vuori (1994, 1995, 1997a, 1997b). Tuoreen perusteellisen Suomen teollisuutta käsittelevän tutkimuksen mukaan ulkoisvaikutuksia syntyy ainakin samalla teollisuudenalalla toimivien yritysten kesken. Tässä tutkimuksessa todetaan edelleen, että tuotekehityksen yhteiskunnallinen tuotto on noin 10 %:a yksityistä tuottoa korkeampi (Rouvinen, 1999). On myös olemassa uutta näyttöä, joka korostaa Suomen teollisuus- ja palveluyritysten innovaatiotoiminnan yhteistyöjärjestelyjen laajuutta ja tärkeyttä (Leiponen, 2000a; 2000b). Katso myös OECD (1999, kuva 4.5 ja [Annex] taulukko 4.5.1).

1 Suomalaisten yritysten T&K-toiminta[4]

1980-luvun tasainen tutkimus- ja kehitystoimintaan (T&K) kohdistuvien investointien kasvu kiihtyi 1990-luvun aikana. 1980-luvun alussa Suomi sijoitti kotimaisissa brutto-T&K-menoissa mitattuna noin 1 %:n BKT:sta T&K-investointeihin. Vuosikymmenen vaihteessa tämä osuus oli noussut 2 %:n tasolle ja saavutti vuosituhannen loppuun mennessä 3 %:n tason. Nämä T&K-satsaukset ovat nostaneet Suomen samaan kärkiryhmään Japanin, Etelä-Korean, Ruotsin ja Yhdysvaltojen kanssa.

T&K-menojen ilmiömäinen kasvu viime vuosikymmenen loppua kohti oli tulosta yksityisen sektorin ja hallituksen vuoden 1996 yhteissitoumuksesta nostaa T&K-menot 2,9 %:iin BKT:sta vuoteen 1999 mennessä. Tämä tavoite saavutettiin itse asiassa jo vuonna 1998. Merkittävä osa julkisesta T&K-rahoituksesta tuli valtio-omisteisten yritysten myynnistä. Nämä varat ohjattiin etupäässä teknologiaan, tiettyihin perustutkimuksen kohteisiin ja koulutukseen. Tähän Suomen teknologiapolitiikan uudistukseen liittyen hyväksyttiin vuonna 1997 myös uusi teollisuustukien yleisiä ehtoja koskeva asetus. Näiden uusien määräysten myötä koko tukijärjestelmä asetettiin jatkuvan arvioinnin alaiseksi.[5] Vuoden 2004 tavoitteeksi on asetettu 3,5 %:a BKT:sta.

Muiden OECD-maiden tapaan kasvava osuus T&K-toiminnasta suoritetaan yrityssektorilla. Vuonna 1997 lähes 70 %:a T&K:sta tuli yrityksiltä, kun luku 1980-luvun alussa oli 55 %:a ja vuonna 1990 62 %:a. Kuvaan kuuluu, että yrityssektorin T&K-intensiteetin (teollisuuden kotimaisessa kokonaistuotannossa) vuotuinen kasvuvauhti on 1990-luvun alusta alkaen ollut yksi OECD-alueen kovimmista (7,3 %:a). Vuonna 1997 yritysten T&K-intensiteetti oli 2,7 %:a. Ainoastaan Ruotsissa luku oli suurempi (4,4 %:a). Yritysten T&K-intensiteetin kasvu johtuu lisääntyneestä T&K-aktiviteetista käytännössä kaikilla toimialoilla, tehdasteollisuudesta palveluihin.

Yrityssektori ei ainoastaan suorita, vaan myös rahoittaa kasvavan osan T&K-toiminnasta. 1980-luvun alussa sen rahoitusosuus oli 55 %:a, josta se on kasvanut lähes 63 %:iin (v. 1997). Mitattuna prosentteina BKT:sta, vastaa tämä nousua 0,65:stä 1,75 %:iin, mikä on jälleen OECD-alueen huippuarvo. Samalla valtiovallan T&K-rahoituksen suhteellinen merkitys on pienentynyt. Tämä ei johdu julkisten rahoituslähteiden vähene-

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4 Tämä jakso perustuu pääpiirteissään OECD:n (1999), EC-DGXII:n, Eurostatin (1999) ja Tilastokeskuksen T&K-tilastosarjojen tietoihin.

5 Yksityiskohtaisemman selostuksen sisältää esim. Kauppinen (1998).

misestä, vaan julkisen T&K-rahoituksen kasvuvauhdin hitaudesta yksityisen rahoituksen kasvuvauhtiin verrattuna.[6] Valtion T&K-rahoituksen osuus BKT:sta pysyi 0.8–0.9 %:n tasolla suurimman osan 1990-lukua (1980-luvulla luku oli alle 0,7 %:a) ja nousi noin 1 %:iin vuosien 1998 ja 1999 huomattavan lisäyksen johdosta. Prosentteina yrityssektorin T&K-menoista valtion rahoitusosuus on kuitenkin edelleen yksi matalimmista OECD-alueella (alle puolet OECD:n keskiarvosta).

T&K-tuen lisäksi valtio tarjoaa myös muunlaista teollisen teknologian rahoitusta. OECD:n laskelmien mukaan on valtion teollisen teknologiatuen osuus Suomen teollisuuden kotimaisesta kokonaistuotannosta ollut yli 0,6 %:a lähes koko 1990-luvun ajan. Tämä on itse asiassa korkein luku niiden kymmenen OECD-maan joukossa, joista kyseisiä tietoja on saatavilla. Lisäksi, toisin kuin monissa muissa maissa, yleissuuntaus Suomessa on kasvava eikä aleneva. Samanaikaisesti on valtion tuen eri osien tärkeysjärjestys muuttunut niin, että taloudelliset kannustimet, etupäässä yritysten T&K-toiminnan avustukset ja tukipalkkiot, ovat kasvaneet tasaisesti yhä tärkeämmäksi osatekijäksi (noin 30 %:sta 1990-luvun alussa 45 %:iin vuonna 1997). Nämä perusteelliset rakennemuutokset kuvaavat suomalaisen teknologiapolitiikan 1990-luvulla tapahtunutta uudelleenorientoitumista.

Kaiken kaikkiaan, niin historiallisesta kuin OECD-perspektiivistäkin tarkasteltuna, Suomen yksityinen ja julkinen T&K-rahoitus oli 1990-luvulla erinomaista. Panosten ja tuotosten suhde ei innovaatiotoiminnassa kuitenkaan ole – kuten tunnettua – välttämättä lineaarinen. Tästä johtuen on erittäin perusteltua kysyä mikä on ollut näiden suunnattomien yritysten T&K-toimintaan kohdistuneiden investointien vaikutus innovaatio- ja talouskehityksellä mitattuna. Tämän tutkimuksen aiheena on etsiä vastauksia edellä esitettyyn kysymykseen.

2 Tutkimuksen tarkoitus

Tämän tutkimuksen päätarkoituksena on tarkastella sekä deskriptiivisen analyysin että ekonometrisen mallinnuksen avulla T&K-menojen ja yritysten taloudellisen suorituskyvyn välistä keskinäistä suhdetta. Erityistä huomiota kiinnitetään valtion rahoittamaan yritysten T&K-toimintaan.

Toisin sanoen, tarkoituksena on arvioida yritysten T&K-investointien taloudellisia hyötyjä, joista erityisen mielenkiinnon kohteena ovat

[6] Katso Tilastokeskuksen julkaisemat T&K-tilastot ja esim. OECD (1998, 2000).

julkisesti rahoitettujen T&K-investointien taloudelliset tulokset. Tässä tutkimuksessa ei oteta kantaa siihen, pitäisikö valtion tukea yrityssektorin T&K-toimintaa vai ei. Valtion tuen nykymuodon tehokkuutta ei myöskään arvioida. Tämänpäivän Eurooppa vaikuttaa saavuttaneen laajan konsensuksen ensimmäisen kysymyksen osalta, sillä valtion tuki T&K-toiminnalle saa yleensä suopean kohtelun Euroopan unionin omaksumissa valtion avustuksia koskevissa säännöksissä.[7] Lisäksi Suomen teknologiapolitiikan strategia korostaa valtion interventioiden tarvetta vähennettäessä riittämättömistä tutkimus-, kehitys- ja koulutusinvestoinneista johtuvia markkinahäiriöitä.[8] Jälkimmäinen kysymys on – sekä teoreettisesti että empiirisesti – huomattavasti haastavampi. Vaikuttaa ilmeiseltä, että tämä on myös pääsyy siihen, miksi se on tähän mennessä saanut osakseen niin vähän huomiota.[9]

Tässä teoksessa selostetut tutkimusarviot ovat eri syistä johtuen joiltakin osin rajoittuneita. Tutkimus käsittelee ensiksikin vain julkista tukea, joka kohdistuu T&K-investointeihin ja joka lisäksi on etupäässä vain Teknologian kehittämiskeskuksen (Tekesin) kautta kulkevaa tukea. Tekes on sovelletun ja teollisen T&K:n päärahoituslaitos Suomessa, ja sen budjetin määrää valtio. Tekes onkin viimeisen vuosikymmenen aikana vastannut 75–80 %:sta teollisuusyritysten saamasta julkisesta T&K-rahoituksesta. Tekesin vuosikertomuksista käy myös ilmi, että sen osuus 1990-luvun puolivälin jälkeen rahoitettujen tuotekehityshankkeiden kokonaiskuluista on keskimäärin ollut noin 40 %.

Toisaalta analyysit pohjautuvat ainutlaatuiseen Tilastokeskuksen yritys-/toimipaikkatason tietokantaan, joka on saatu aikaan yhdistämällä yrityksiä, toimipaikkoja ja niiden työntekijöitä koskevat hallinnolliset rekisterit toisiinsa. Tähän tietokantaan on lisätty tietoja myös Tekesin rahoitusrekistereistä. Tietokanta esitellään pääpiirteissään kolmannen luvun liitteessä. Muiden lukujen teksteissä on lisäksi yksityiskohtia ja lisätietoja. Tietojen päivitysviiveen takia analyysejä ei kuitenkaan voida ulottaa vuotta 1998 pitemmälle. Tästä johtuen tutkimukset kattavat vain osittain muutaman viime vuoden aikana tapahtuneen julkisen T&K-

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[7] Katso lisää aiheesta esim. Walther ja Joels (1998). Yleisluontoisempaa keskustelua julkisen vallan liike-elämän innovaatioihin kohdistuvan tuen oikeutuksesta sisältää esim. Pretschker (1998).

[8] Enemmän aiheesta on esim. teoksessa Kauppinen (1998).

[9] Martin ja Scott (2000) esimerkiksi korostavat, että koska innovaatiomarkkinoiden häiriön aiheuttavat voimat vaihtelevat sektori sektorilta, täytyy tämä ottaa huomioon myös muotoiltaessa julkista tukea, joka suunnataan yksityiseen innovaatiotoimintaan.

rahoituksen voimakkaan kasvupyrähdyksen. Toisaalta T&K-investoinnit, rahoituslähteestä riippumatta, vaikuttavat tuotantoon huomattavalla viiveellä. Julkisen ja yksityisen sektorin viime vuosien yhteiset T&K-panostukset voidaan siten arvioida kunnolla aikaisintaan vasta muutaman vuoden päästä.

Kolmanneksi, T&K-satsausten taloudellista tulosta arvioidaan ainoastaan kahden, mutta sitäkin tärkeämmän, ulottuvuuden kautta: yhtäältä suhteessa yrityksen tuottavuuteen, ja toisaalta suhteessa yrityksen työpaikkojen luomiskykyyn. Tässä tavoitteena on havaita ja mitata mahdolliset suorat yhteydet yritysten T&K-menojen ja tuottavuus- ja työllisyyskehityksen välillä. Mahdolliset epäsuorat vaikutukset jätetään etupäässä spekulaatioiden varaan. Analyyseissä käytetään hyväksi myös pientä joukkoa yritysten innovaatiotoiminnan tuloksia ilmaisevia indikaattoreita. Sen lisäksi, että nämä indikaattorit ovat mielenkiintoisia itsessään, antavat ne mahdollisuuden ottaa T&K-toimintojen lisäaspekteja mukaan analyysiin. Seuraavissa tutkimuksissa esiintulevien innovaatiotulosten mittareiden joukkoon kuuluvat mm. patentit ja indikaattorit, jotka kuvaavat sitä, onko yritys analysoitavan ajanjakson aikana tuonut markkinoille uusia tai paranneltuja tuotteita ja/tai prosesseja vai ei.[10]

Lopuksi, erillään laajemmasta koko yrityssektorin analyysistä, yritetään kartoittaa myös yritysten välisiä eroja omien T&K-menojen ja julkisen T&K-tuen suhteen sekä näiden erojen merkitystä kyseisten yritysten taloudellisen suorituskyvyn kannalta. Huomio kiinnitetään kahteen olennaiseen tekijään: toimintasektoriin – teollisuus- vai palvelu-sektorin yritys – ja kokoon – iso vai pieni yritys. Kummallakin tekijällä on suuri merkitys Suomen tämänhetkisen teknologiapolitiikan kan-nalta[11], ja pienet ja palvelusektorin yritykset ovat nopeasti kasvattaneet osuuttaan Tekesin myöntämästä T&K-rahoituksesta. Kuten seuraavissa luvuissa esitellyistä tuloksista huomataan, voi eri sektorin ja kokoluokan perusteella tehdä kuitenkin vain varovaisia päätelmiä. Tähän on pääsyynä se, että pienet ja palvelusektorin yritykset ovat edelleen aliedustettuina saa-

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[10] Huomionarvoista on, että myös OECD mittaa yritysten innovaatiotuloksia käyttäen näitä kahta indikaattorityyppiä. Katso OECD (1999, jaksot 11.2 ja 11.4).

[11] Vastoin OECD:n keskiarvotrendiä, Suomessa valtion yrityksille myöntämä T&K-rahoitus on painottunut eniten pieniin yrityksiin (OECD, 1999). Vuonna 1997 valtion osuus yritysten koko T&K-rahoituksesta oli huomattavasti korkeampi pienissä kuin suurissa yrityksissä; se oli keskimäärin 8,2 %:a alle 500:n työntekijän yrityksissä ja 11,7 %:a alle 100:n työntekijän yrityksissä. Yli 500:n hengen yrityksissä luku oli 2,4 %:a ja yli 1000:n henkilön yrityksissä 1,5 %:a. Suuret yritykset (yli 500 työntekijää) rahoittavat kuitenkin suurimman osan yritysten omasta kokonais-T&K-rahoituksesta (71 %:a vuonna 1997).

tavilla olevassa yritystason aineistossa. T&K-tilastojen jatkuvasti parantuva kattavuus näiden kahden yritystyypin osalta on johtanut myös niiden T&K-osuuden tasaiseen kasvuun. Tämä vaikuttaa tietysti saavutettuihin tutkimustuloksiin.

3 Sisällön yhteenveto ja kirjan lukujen kes-keiset tulokset

Loppuosa tästä johdantoluvusta luo katsauksen lukujen 2–4 keskeisiin tuloksiin. Luku 2 sisältää moniulotteisen yritysten taloudellista suorituskykyä mittaavan deskriptiivisen vertailun tuettujen ja tukea saamattomien yritysten välillä. Luvut 3 ja 4 laajentavat analyysiä ekonometriseen julkisen T&K-tuen ja tuottavuuskehityksen, sekä julkisen T&K-tuen ja työpaikkojen luomiskapasiteetin välisten suhteiden mallinnukseen. Kirjan kahta liitelukua ei kommentoida yksityiskohtaisesti. Ensimmäinen liiteluku, jonka on kirjoittanut *Synnöve Vuori*, esittelee lyhyen katsauksen olemassaoleviin, etupäässä Suomea koskeviin, tämän kirjan aihealueeseen kuuluviin empiirisiin tutkimuksiin. Toinen liiteluku, jonka on kirjoittanut *Antton Lounasheimo*, käsittelee yleisemmästä näkökulmasta tämänhetkistä Suomessa vallitsevaa tietämystä teknologian ja työpaikkojen välisestä yhteydestä.

3.1 Teknologiayritykset ja julkinen T&K-rahoitus: deskriptiivinen johdanto

Luku 2 sisältää *Olavi Lehtorannan* monipuolisen katsauksen Tekesin – valtion yrityssektorille suunnattujen T&K-lainojen ja suorien tukien pääjakelukanavan – julkituomaan julkisen sektorin T&K-tukea koskevaan dataan. Samalla tämä luku tutustuttaa lukijan luvuissa 3 ja 4 selostettujen julkisen T&K-rahoituksen tuettujen yritysten tuottavuuteen ja työpaikkojen luomiskykyyn kohdistuneiden vaikutusten arvioinnin pohjana olevaan data-materiaaliin.

Tuettujen yritysten määrän ja levinneisyyden tarkasteluun yhdistetään runsas joukko eri näkökulmia, mukaanlukien datan yhdistely- ja rajaamistavan oikeutus ja asianmukaisuus. Lehtoranta ei vain tee havaintoja tuetuista ja ei-tuetuista yrityksistä, vaan tutkii lisäksi T&K-tuen tiheyttä (hyväksyttyjen ja hylättyjen projektien avulla), yritysten pitkäjänteisyyttä (säännöllinen vai sattumanvarainen hakija) ja T&K-tuen maksuvuosien lukumäärää. Tutkitulla ajanjaksolla 1991–1998 on havaittavissa eräs selkeä kehityssuunta: pienempien ja palvelusektorin yritysten lisääntyvä dominanssi tukea saaneiden yritysten joukossa. Tämä kuuluu edellä lyhyesti mainittuun Suomen teknologiapolitiikan 1990-luvulla tapahtuneeseen uudelleenorientoitumiseen.

Tuettujen ja tukea saamattomien yritysten välinen monipuolinen vertailu paljastaa useita mielenkiintoisia yhtäläisyyksiä ja, ennen kaikkea, eroja näiden kahden ryhmän välillä. Päätulosten tulkinta antaa aiheen seuraavaan varovaiseen yleistykseen: tuetuilla yrityksillä on keskimäärin korkeampi tuottavuuden taso ja tuottavuuden kasvuvauhti. T&K-tuen ja tuottavuuden kasvun välinen yhteys näyttää lisäksi ajan kuluessa vahvistuneen erityisesti palvelusektorin yritysten osalta. Kuitenkin suurten yritysten kohdalla nimenomaan tukea saamattomat ovat pysyvästi omanneet nopeamman tuottavuuden kasvuvauhdin.

T&K-intensiteetti (T&K-menot per liikevaihto) osoittautuu huomattavasti korkeammaksi tuetuissa yrityksissä. Toisaalta niin tuetuissa kuin tukea saamattomissakin yrityksissä (sekä teollisuus- että palvelusektorilla) T&K-intensiteetin taso yleensä nousee ajan myötä, mutta laskee yrityksen koon kasvaessa. Koko ei aiheuta yhtä suuria eroja yrityssektorin oman T&K-rahoituksen ollessa kyseessä, mikä edelleen tukee ajatusta valtion T&K-rahoituksen suhteellisesti suuremmasta merkityksestä pienille yrityksille (katso alaviite 11 edellä).

Myös pääomaintensiteetin taso (pääomakanta/työntekijä) osoittautuu huomattavasti korkeammaksi tuetuissa yrityksissä, mutta pysyvästi vain teollisuusyritysten osalta. Kuvio on vähemmän selkeä palveluyritysten kohdalla. Yleisvaikutelma on kuitenkin se, että silloinkin kun tuettujen yritysten kategorian keskimääräinen pääomaintensiteetin taso jää tukea saamattomien yritysten kategorian tason alapuolelle, ero ei ole suuri. Lehtoranta tuo esiin hypoteesin, jonka mukaan uusien informaatioteknologioiden kehitys on saanut Tekesin siirtämään palvelusektorin yrityksille suunnatun T&K-tuen korkean pääomaintensiteetin yrityksiltä korkean T&K-intensiteetin yrityksille.

Tuettujen yritysten verrattain korkean T&K-intensiteetin valossa ei ole yllättävää, että patentointi on T&K-tukea saavien yritysten joukossa huomattavasti yleisempää kuin tukea saamattomilla. Nämä yritykset ovat myös alttiimpia tuote- ja prosessi-innovaatioille. Ero tuettujen ja ei-tuettujen yritysten patentointikäyttäytymisessä on silmiinpistävin suurimmassa kokoluokassa. Myös korkeasti koulutettujen, tutkinnon joko insinööritieteessä tai luonnontieteissä omaavien, työntekijöiden suurempi osuus tuetuissa yrityksissä on niiden korkeamman T&K-intensiteettitason pohjalta tarkasteltuna odotusten mukaista. Hyvin koulutettu tutkimushenkilökunta on selvästi yksi Tekesin kriteeri arvioitaessa T&K-tukihakemuksia.

3.2 Yksityisesti ja julkisesti rahoitetun T&K:n vaikutus suomalaisten yritysten tuottavuuteen

Yrityksiä selvittää julkisen T&K-tuen tuottavuutta kiihdyttävää vaikutusta on Suomen osalta ollut vain muutamassa tutkimuksessa. *Mika Malirannan* analyysi luvussa 3 eroaa näistä aikaisemmista tutkimuksista sekä lähestymistapansa, metodinsa, että käytetyn tilastoaineiston osalta. Julkista yrityksille kohdistuvaa T&K-rahoitusta koskevat pääasialliset havainnot ovat kuitenkin pohjimmiltaan samoja kuin edeltävissäkin tutkimuksissa: julkisella tuella on vain vähäinen suora positiivinen vaikutus tuettavien yritysten tuottavuuskehitykseen. Sama johtopäätös vedetään myös yksityisesti rahoitetun T&K-toiminnan osalta. Tätä lopputulosta selittävät kuitenkin ainakin osittain tutkimusajanjakson, eli vuosien 1988–1996, turbulentit ja monin tavoin erikoislaatuiset taloudelliset olosuhteet.

Se, käytetäänkö tuottavuusmittarina työvoiman tuottavuutta vai kaikkien tuotannontekijöiden tuottavuutta, ei erityisemmin vaikuta tutkimuksen tuloksiin. Tuottavuuden kasvun mittaamiseen käytetyn ajanjakson pituudella ei myöskään ole pääasiallisten tutkimustulosten kannalta merkitystä. T&K:n aiheuttama merkityksettömän pieni tuottavuuden kasvun kiihtyminen on havaittavissa sekä teollisuus- että palvelusektoreilla ja eri yrityksissä niiden kokoluokasta riippumatta.

Yrityksen omiin T&K-panostuksiin verrattuna vaikuttaa yrityksen teollisen ympäristön T&K-intensiteetillä olevan huomattava vaikutus yrityksen tuottavuuteen. Tämä viittaa siihen, että julkinen T&K-politiikka ja valtion interventiot mitä ilmeisimmin nostavat tuottavuutta diffuusiomekanismien välityksellä. Näistä on apua yrityksille uusien teknologioiden omaksumisessa ja hyväksikäytössä. Tällaiset toimialakohtaiset ulkoisvaikutukset ovat hyödyllisiä yrityksille riippumatta siitä saavatko ne tukea vai eivät. Ne osoittautuvat erikoisen hyödyllisiksi pienille yrityksille. Malirannan hypoteesin mukaan isot yritykset toimivat monella eri toimialalla ja siitä johtuen päätoimialan T&K-ulkoisvaikutukset eivät ole niille yhtä ratkaisevia kuin pienemmille firmoille.

Yritys- ja toimialakohtaisen T&K-intensiteetin lisäksi Maliranta tarkastelee laajaa joukkoa muita taustatekijöitä, joiden voidaan olettaa vaikuttavan tuottavuuden kasvuun. Yrityksen työntekijöiden korkean koulutusasteen havaitaan – yhdenmukaisesti aikaisempien tutkimusten kanssa – kasvattavan selvästi tuottavuutta. Korkeasti koulutettujen osuudessa tapahtuvien muutosten vaikutukset ovat toisaalta vähemmän selkeitä. Varovaisen tulkinnan mukaan insinööri- tai luonnontieteissä korkeamman tutkinnon omaavien työntekijöiden osuuden nousu johtaa tuottavuuden nousuun lähinnä vain teollisuusyrityksissä ja niissäkin vain pitkällä aikavälillä. Vastakohtaisesti palvelusektorin yritysten tuottavuuskehitykseen tuntuu vaikuttavan enemmän korkeakoulukoulutuksen jossakin muussa kuin insinööri- tai luonnontieteissä saaneiden osuuden kasvu. Nämä tuottavuusvaikutukset tulevat myös esiin paljon nopeammin kuin teknisen koulutuksen saaneen työvoiman aikaansaamat vaikutukset. Yksi mahdollinen selitys näille eroavuuksille on se, että palvelusektorin yritykset ovat paljon riippuvaisempia lyhyen tähtäimen tuottavuuden lisääntymisestä ja investoivat tästä johtuen mieluummin muihin kuin teknisiin taitoihin. Teollisuusyritysten toiminnassa taas tuotekehityksellä on keskeinen osa ja tästä johtuen ne ovat voimakkaammin fokusoituneita edullisen tuottavuuskehityksen vaalimiseen pitkällä tähtäimellä. Havaittu tuoteinnovaatioiden positiivinen vaikutus tuottavuuden kasvuun voidaan nähdä tämän väitteen tukena.

Maliranta toteaa myös ulkomaalaisomisteisten yritysten taipumuksen saavuttaa kotimaisessa omistuksessa olevia yrityksiä nopeamman tuottavuuden kasvuvauhdin. Tämä ero yritysten tuottavuuskehityksissä ei kuitenkaan näytä johtuvan niiden erilailla tuottavuuteen vaikuttavista T&K-ponnisteluista; Maliranta ei löydä samansuuruista eroa T&K-toiminnan tuotoissa ulkomaisessa ja kotimaisessa omistuksessa olevien yritysten välillä.

Maliranta miettii lopuksi mahdollisia keinoja, joilla T&K-panostusten ja tuottavuuden kasvun välisen yhteyden analyysiä voitaisiin kehittää. Monista eri mahdollisuuksista erityisesti parempilaatuisen datan luominen olisi ratkaisevan tärkeää.

3.3 Luodaanko työpaikkoja teknologista kehitystä tukemalla? – Näyttöä suomalaisilta toimipaikoilta

Luvussa 4 *Mika Maliranta* selostaa uraauurtavassa tutkimuksessaan työpaikkojen luomiskyvyn kehitystä suomalaisissa tehdaslaitoksissa ja toimipaikoissa vuosien 1986 ja 1998 välisellä – taloudellisen kehityksen kannalta turbulentilla – ajanjaksolla. Painopiste on eri T&K-intensiteetin ja koon omaavien teollisuuden toimipaikkojen vertailussa ja näiden tietojen vertaamisessa palvelusektorin T&K-intensiteetin ja työpaikkojen luomiskyvyn suhteeseen. Tutkimuksen yksi tärkeä ulottuvuus on myös valtion rahoittamien T&K-panostusten vaikutusten tarkastelu työllisyyden kasvun näkökulmasta.

Maliranta selostaa työpaikka- ja työntekijävirtojen kokoa ja suuntausta käyttäen hyväkseen laajaa joukkoa eri selventäviä mittareita, joiden laskemisen on tehnyt mahdolliseksi ainutlaatuisen toimipaikkatason aineiston hyväksikäyttö. Kyseiset mittarit on määritelty ja käyty huolellisesti läpi tekstissä. Seuraavat erilliset osatutkimusten kohteet tuottavat useita mielenkiintoisia tuloksia: (1) eri T&K-intensiteetin omaavat tehdaslaitokset, (2) pienet eri T&K-intensiteetin tehdaslaitokset, (3) Tekesin tukemat/ei-tukemat tehdaslaitokset ja (4) eri T&K-intensiteetin toimipaikat palvelusektorilla.

Teollisuussektorille laskettujen eri virtausvauhtien perusteella on korkean T&K-intensiteetin toimipaikoilla ollut paras sekä työpaikkojen luomis- että nettotyöllisyyskehitys 1990-luvun alun syvää lamaa seuranneen talouden elpymisen ajanjaksolla. Työpaikkojen luomiskyvyn havaitaan kuitenkin vaihdelleen huomattavasti korkean T&K-intensiteetin toimipaikoissa. Tämä heterogeenisyys antaa ymmärtää, että korkea T&K-intensiteetti ei välttämättä ole tae toimipaikan hyvästä työpaikkojen luomiskyvystä. Yhteys T&K-panostusten ja työllisyyden kasvun välillä osoittautuukin paljon selkeämmäksi, vaikkakin heikommaksi, keskitason T&K-intensiteetin toimipaikkojen keskuudessa. Lisäksi korkean T&K-intensiteetin toimipaikkojen vahva työpaikkojen (netto-)- luomiskyky osoittautuu kuuluvan yhteen myös verrattain korkean työntekijöiden vaihtuvuuden kanssa. Maliranta esittää hypoteesin, jonka mukaan erityisesti korkean T&K-intensiteetin toimipaikoissa luodut uudet työpaikat ovat edellyttäneet myös uudenlaisia taitoja ja tämä on käynnistänyt laajamittaisen työtehtävien ja -taitojen yhteensovittamisprosessin näissä toimipaikoissa.

Palvelusektorin toimipaikoille lasketut työpaikka- ja työntekijävirrat ovat huomattavan samankaltaisia teollisuuden toimipaikoille saatujen tulosten kanssa. Toisin sanoen, korkean, keskitason ja matalan T&K-intensiteetin toimipaikat näyttävät käyttäytyvän työpaikkojen luomisen ja työvoiman uudelleenjärjestelyn suhteen pitkälti samalla tavalla sektorista riippumatta. Tämä tulos viittaa samaan suuntaan kuin toinen tuore tutkimus, jossa innovaatiotoiminnan havaittiin olevan hyvin samanlaista Suomen teollisuus- ja palvelusektoreilla (Leiponen, 2000a).

Teollisuussektorin tulokset muuttuvat vähemmän huomiotaherättäviksi, jos vertailu rajoitetaan pieniin alle 50:n työntekijän toimipaikkoihin ja, edelleen, laman jälkeiseen ajanjaksoon. Eri T&K-intensiteetin

omaavien pienten toimipaikkojen väliset virtauserot ovat suurimmilta osin kaventuneet ja toisinaan jopa käyneet merkityksettömiksi lamaa seuranneen periodin aikana. Näiden työntekijä- ja työpaikkavirtojen välittämä yleiskuva on kuitenkin se, että pienet, matalan T&K-intensiteetin toimipaikat luovat edelleen vähiten uusia työpaikkoja ja olemassaolevat työpaikat ovat niissä kaikkein epävakaimpia. Samansuuntaisia tuloksia sisältää tuore yksilötason aineistoa hyväksikäyttävä Suomen tehdasteollisuuden työntekijöiden työttömyysriskejä käsittelevä tutkimus (Asplund, 2000).

Maliranta vertailee lopuksi Tekesiltä tukea saaneita ja saamattomia teollisuusyrityksiä ja -toimipaikkoja keskenään ja havaitsee, että tuetut yksiköt ovat erityisesti viime vuosina myötävaikuttaneet nettotyöllisyyden kasvuun huomattavasti ei-tuettuja yrityksiä enemmän. Mitattuna lopetettujen työpaikkojen määrällä, tuetut yritykset näyttävät myös pystyneen tarjoamaan vakaampia työpaikkoja. Verrattuna ei-tuettuihin keskitason tai korkean T&K-intensiteetin yrityksiin, ne ovat kuitenkin rekrytoineet työttömiä keskimäärin hieman hitaammalla vauhdilla.

Ekonometrisen analyysin päätulokset ovat periaatteessa yhdenmukaisia deskriptiivisen tarkastelun yleisluontoisempien havaintojen kanssa. Yrityksen yhteenlasketuilla T&K-panostuksilla ja toimialakohtaisella T&K-intensiteettitasolla – yrityksen T&K-ympäristöllä – havaitaan olleen positiivinen vaikutus nettotyöllisyyden kasvuun teollisuudessa. Yrityksen T&K-panostusten selkeä positiivinen vaikutus työpaikkojen luomisen suhteen säilyy myös rajattaessa muuttuja kuvaamaan ainoastaan yksityisesti rahoitettua osaa yrityksen T&K-menoista. Jäljelle jäävälle julkiselle osuudelle saadaan samassa yhteydessä suuri, mutta tilastollisesti merkityksetön arvo. Näyttö julkisen T&K-tuen suorasta vaikutuksesta tuettujen yritysten työpaikkojen luomiskykyyn jää siis toisin sanoen epäselväksi.

Kuten 3:nnen luvun tuottavuuden kasvuanalyysin tapauksessa, myös työpaikkojen luomiseen liittyy ilmiselvästi tärkeitä diffuusiomekanismeja. Tätä ilmentää selvimmin toimialakohtaisen T&K:n positiivinen vaikutus nettotyöllisyyden kasvuun. Kun vielä otetaan huomioon, että toimialakohtainen T&K-intensiteetti paransi myös yritysten tuottavuuskehitystä ja tuottavuuden kasvu on yhteydessä työpaikkojen luomiskykyyn, vaikuttaa toimialan kokonais-T&K:n määrä olevan tässä yhteydessä ratkaisevan keskeinen tekijä. Nämä tutkimustulokset kuuluvat samaan joukkoon muiden, jatkuvasti lisääntyvien, empiiristen tulosten kanssa, jotka vahvistavat yritysten T&K-toiminnan ulkoisvaikutusten tärkeyden ja joiden voidaan tästä johtuen väittää muodostavan pääasiallisen perusteen innovaatiomarkkinoiden häiriöitä vähentävän ja koko talouden tuottavuus- ja työllisyyskehitystä tukevan julkisen T&K-tuen jakamiselle.

Seuraavaksi Maliranta laajentaa ekonometristä tarkasteluaan kattamaan teollisuusyrityksen kokoluokan vaikutuksen. Saadut tutkimustulokset osoittavat luovan ympäristön olevan erityisen merkityksellinen työllisyyden nettokasvulle pienissä ja keskisuurissa yrityksissä, kun taas suurissa teollisuusyrityksissä työpaikkojen luomiskapasiteetin kannalta huomattavasti tärkeämpiä ovat yrityksen sisäiset T&K-panostukset. Yrityksen T&K:n julkista osuutta kuvaavien muuttujien yhdistäminen koko-dummy-muuttujiin ei lisää tuloksiin mitään uutta. Julkinen T&K-rahoitus ei siis suoraan vaikuta nettotyöllisyyden kasvuun minkään kokoluokan teollisuusyrityksissä (paitsi yhdistelmässä suuret yritykset ja ei-Tekesin myöntämä tuki).

Palvelusektorin yritysten ekonometrisen tarkastelun tulokset seuraavat pääosiltaan teollisuusyrityksille saatuja tuloksia. Tulokset ovat yhdenmukaisia myös yrityksen T&K-toiminnan julkisesti rahoitetun osuuden tarkastelun ollessa kyseessä.

Maliranta lopettaa analyysinsä korostamalla sen sisältämää vahvaa empiiristä tukea väitteelle, jonka mukaan suuresti T&K-toimintaan panostavilla yrityksillä on ratkaiseva asema uusien ja pysyvien työpaikkojen synnyttämisessä. Tässä mielessä erityisesti korkean T&K-tason yritysten voidaan olettaa vähentävän työttömyyttä. Maliranta vie tarkastelunsa kuitenkin astetta pidemmälle ja ottaa mukaan vielä yhden näkökulman, nimittäin nykyisen työvoimaan kohdistuvan kysynnän rakenteen ja erityisesti matalasti koulutettujen työttömien ilmeisen heikot mahdollisuudet löytää työtä työpaikkoja luovista korkean teknologian ja tuottavuuden yrityksistä. Tämä aspekti on merkityksellinen myös suhteessa julkiseen T&K-rahoitukseen, sillä kasvava osa siitä menee korkean – joko nykyisen tai potentiaalisen – suorituskyvyn yrityksille, joiden kysyntä korkeasti koulutettuja työntekijöitä kohtaan kasvaa.