Working Paper

Education, Tenure and Innovation in Manufacturing Firms

Aija Leiponen

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Abstract

This study describes the stock of education and firm-specific work experience in a sample of Finnish manufacturing firms. The focus is in particular on the interaction of these competence measures with innovation. Generally speaking the levels of education are rising. Especially, the share of employees with a technical or natural scientific degree is increasing, together with the number of post-graduate degree employees. However, the sectoral differences are considerable. Industries of rapid technological change are very intensive in general and higher technical competences. In capital intensive industries, instead, the average tenure is clearly longer and the level of education lower.

The differences between innovating and non-innovating firms are examined, as well. Innovating firms have a more educated labor force, and they are more profitable than non-innovators. The better economic performance may result from the flexibility of innovating firms. For instance, they recovered clearly more rapidly from the economic slump of the turn of the decade 1980-90.

Product and process innovating firms are characterized also with principal components. The results lend support to the hypothesis that the size of the the firm affects the composition of R&D. It is observed that non-innovators are small and stagnating firms. Product innovators are slightly bigger, rather labor intensive, and endowed with high and increasing levels of general and technical competences. Comprehensive innovators, i.e. firms carrying out both product and process innovation remind in many respects product innovators, but are bigger, and have started to decrease their labor intensity. Finally, process innovators are the largest firms on average. Their labor intensity is significantly lower, and they rely more on research competences than general or technical skills.

Key words: education, innovation, profitability, life cycle

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Education, Tenure and Innovation in Manufacturing Firms

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1 Introduction

The economic importance of knowledge and competences is often stressed in the economic and political debate, but little concrete research has been done at the firm level. Partially this is due to the immaterial nature of knowledge, its direct measuring and conceptualizing is quite impossible. Also, in view of knowledge embodied in people, the property rights problems have possibly impeded the incorporation into the theories of the firm. As a result, the theories concerning employees in a firm have centered around incentives and contracting. However, I argue that since knowledge is a fundamental ingredient in the evolution of firms, these problems should not prevent the analysis.

Competences and skills, which are partly reflected in educational attainment and work experience, influence the capabilities to learn and innovate. It is not the case that firms' employees are a random draw from the skill distribution supplied in the labor market. Instead, there are persistent skill differentials among firms, even within industries. It is a crucial aspect of the knowledge and technology strategy of the firm to employ people who are able to carry out the planned operations.

Moreover, despite the fact that specific skills and knowledge are prerequisite for using advanced technologies and carrying out complex procedures, in the longer run this is not the most important effect of competent employees. Instead, in an evolving environment the abilities to adjust, learn and innovate ar far more crucial. These *dynamic competences* (cf. Dosi and Marengo 1994) enable the firm to create and adopt new knowledge, and to adapt to changes in demand, competitive conditions and technology. Dynamics driven by learning on the job enable the firm to upgrade the operations and procedures, and, in particular, the technology.

Dynamic competences generate a process of accumulating organizational knowledge. I suggest here that measures like education and work experience correlate with the rates of learning and innovation, and eventually with the rate of accumulation of organizational knowledge. Therefore it is worth while to study the inter-firm and inter-industry differences with respect to these indicators.

The study makes use of a firm-level data set on a sample of Finnish manufacturing companies. The data consist of information on educational fields and levels, average years of tenure in the firm, innovation, and firm and industry control variables. This type of a dataset has not been much utilized at the firm-level.

The paper is organized in the following way. In section 2 I briefly discuss the literature on human capital and competences in relation to technological change. Section 3 characterizes the trends in the levels and fields of education and the average tenure over the period of study, 1987-1993. In section 4 the industry-specific differences in demand for competences are described, and the differences between innovators and non-innovators are examined in section 5. Section 6 concludes.

2 A Brief Review of the Literature on Human Embodied Knowledge

2.1 Human Capital

In recent literature on economic growth, human capital and the rate of technological progress have been identified as engines of growth. In industrial economics, technological change has been analyzed extensively as a driving force of long term development. There the role of human capital has been negligible. However, one of the premises of endogenous growth models (e.g. Romer 1990) has been that technical change is a function of the stock of human capital. Hence the next question to ask is: how can we invest in human capital, and what kind of human capital is most important for technological progress?

On the empirical side, one of the outcomes of macroeconomic growth studies has been that the level of education is positively associated with growth (e.g. Benhabib and Spiegel 1994). Similar results were obtained in a study of enterprise growth using firm level data (Leiponen 1995). Despite some obvious econometric problems of this type of regression analyses (e.g. endogeneity), the upshot is that countries and firms that have a more educated workforce tend to grow faster.

The theoretical framework behind growth studies implies that the more human capital investment the faster the growth. However, the relationship cannot be that simple in reality. Therefore it is of vital importance to consider what kind of human capital is economically relevant in which activities and why, and finally, how to accumulate it.

Human capital, most often proxied by educational level, does not seem to behave like physical factors of production. This can be discerned in that the *level* of education, not necessarily the *growth rate* appears to influence economic growth (Benhabib and Spiegel 1994, Barro 1991). There seem to be considerable scale effects and lags involved. These may result at least partly from the anomalies inherent with knowledge. The use and accumulation of knowledge are necessarily social activities as the individuals influence firm performance through the functioning of the organization. The lags in the effects of human capital may be due to the fact that organizational learning and evolution happen rather slowly.

Another possible source of knowledge anomalies are the complementarities and interactions on the one hand between different types of competences in a team, and on the other, between competences, physical capital and technology. For instance, if technological progress induces learning by doing in production, then the dynamically more competent employees learn faster, and as a result adopt more rapidly new knowledge, products and technology. In this case the returns to investment are larger in economic organizations with more competent workers. This leads to more investment in physical capital. There is some evidence on this on the macroeconomic level (e.g. Knight et al. 1993).

2.2 Accumulation of Competences

Economic performance of organizations is based on accumulating competences. Part of the accumulation is direct investment in knowledge through hiring people with relevant education and experience, providing on-the-job training, using consulting services and carrying out R&D. Joint R&D and other types of cooperation with other firms can also be regarded a form of knowledge investment.

Investment in in-house R&D and cooperative research is important to keep up with technological change in the market. In addition to the direct results of R&D like new products or improved processes and methods, researchers themselves learn about technologies, and maintain the capabilities to assimilate knowledge from the outside (Cohen and Levinthal 1990). R&D is therefore an important source of learning opportunities.

Knowledge is accumulated also in more inconspicuous ways through learning. While operating the firm learns about technology, competitors and customers, which enables it to improve its procedures. Learning about the firm's own competences and resources is also important, because it helps to make more pertinent decisions (Jovanovic 1982).

Abilities to learn and innovate are indispensable in particular in a rapidly changing environment (cf. Aoki 1986). Technological and economic change require the firm's personnel to be capable of adopting information concerning technology, markets, and perceiving available opportunities, the exploiting of which calls for innovation. Swift reaction and adaptation are essential for survival under rapid change of the environment.

2.3 Technological Change and the Demand for Competences

It has been argued at least since Schumpeter (1942), that the incentive to do R&D and innovate are the monopoly profits accruing to the developer of a successful novelty, a new product or a process. However, even if the product itself might survive for a long time in the market, monopoly profits are transitory. The production knowledge diffuses usually quite rapidly despite intellectual property rights (e.g. Arrow 1994). The long run competition is therefore about striving for successful R&D. Even being a rapid imitator requires a fair amount of technological knowledge. Hence the most important benefits of R&D are not in the short run profits, but in the whole process of being capable of creating and adopting knowledge, which calls for a considerable competence base.

Innovation can be viewed as a process that transforms the internal capabilities in firms (Geroski et al. 1993). This creates generic differences between innovating and non-innovating firms. Geroski et al. argue, that the effects of innovative capabilities on firm performance are realized in particular through an increased ability to survive in cyclical downturns; innovating firms are less sensitive to business cycle shocks. Capabilities make firms more flexible and adaptive, which enables them to respond to new technological developments, consumer needs and the like.

Technological change and competence accumulation are complementary processes. Young (1993) investigates a process of learning by doing, which is bounded by the state of technology. Without investing in technological change, learning by doing comes to a halt eventually. Bartel and Lichtenberg (1987, 1990) discuss the effects of the age of technology on the demand for learning. New technology provides opportunities for learning, and using technologies often requires the acquisition of new skills. They also maintain that education enhances the learning abilities of the workers. As a consequence, the more rapid the technological change in the firm, the more educated workers are needed.

Learning effects related to each technological *vintage* are explored by Bahk and Gort (1993). Technological vintages proxy technological change embodied in physical capital. Their estimates indicate that firm-specific learning about the characteristics of new machinery and equipment used continues for several years after they have been put in place. In their study, the human capital variable (wages) measures those returns to learning that are captured by the individual workers themselves and not by the firm. They find that human capital is positively associated with the productivity of firms when the vintage effect is controlled for. This lends support to the conjecture by Bartel and Lichtenberg, that highly educated labor's share in the total cost is a function of the age of technology.

To summarize, various authors have identified important interactions between technological change, competences, and learning. New technologies create demand for new skills and learning. On the other hand, if education enhances learning abilities and provides people with skills, it will influence the rate of accumulation of knowledge, and thus also facilitate innovation in firms. Education represents only a small portion of the knowledge residing in firms, and they are the component that the firm may invest in relatively easily. However, this investment seems to create considerable returns, so it is relevant to incorporate it into the studies of firm performance.

3 The Data on Education and Tenure in Finnish Manufacturing Firms

I turn to investigate the levels of education and accumulated firm-specific experience in Finnish manufacturing firms. Obviously, these are only very limited indicators of the capability base in firms. However, education may be an important factor in learning through which firm-specific competences are accumulated. It expands the set of available learning directions, and it is also an important input in the innovation activities (Senker 1994). Therefore, with the level of education it is possible to characterize to some extent the stock of basic skills and knowledge, which form the basis for further creation of knowledge on the job.

Firm-specific knowledge accumulation is described here by the work-experience in the firm, i.e. average job tenure. Average tenure is expected to be higher in industries with slower pace of change of technology or market environment, whereas in industries and firms under rapid change there have to be new skills and capabilities brought in constantly to meet the needs created by the new environment. However, I conjecture that in any industry or firm, too static a labor force leads to halting learning and waning innovativeness and flexibility. There has to be novelty introduced also in the workforce. Operation of an organization is a social process, and new employees bring in new capabilities, which may encourage the revision of the operating procedures. Instead, too rapid a change leads to a chaotic environment, where routines are not developed and where social interaction and communication is hindered. Some stability of relationships between people is a prerequisite for productive interaction.

3.1 Sources of Data

A quite unique firm-level database compiled by Statistics Finland[1] is utilized in the analysis. The educational data describe in detail the formal level attained and the field of education of workers in firms. This is supplemented with some information about occupations and work experience in the current employment, that is, the length of tenure. The innovation data are less detailed, consisting of a survey from the year 1991. The survey provides information about process innovations and product improvements realized between 1989 and 1991, and an estimate of the share of new products in total sales revenue. The data on economic performance are obtained from the firms' financial accounts. They have been deflated with the industrial producer price index. The firms in the sample operate in 15 manufacturing industries. Originally there were about 500 firms in the innovation survey, but due to problems in combining data from different sources and especially the lack of time series on financial information, I ended up with a cross-section of 333 firms and time-series of 209 firms.

The period of analysis was very turbulent, as it coincides with the worst recession in Finland since the 1930s. The data set consists only of firms that survived during the most difficult years, and continued to exist throughout 1985-1993. Firms that had radical changes in size (either expanding or shrinking abruptly) had to be eliminated. This means that firms that were part of mergers or went bankrupt before 1991 are not considered. This might dampen the dynamic features, because only quite smoothly evolving companies are analyzed, but of course the basic underlying dynamics that I wish to grasp should operate in all kinds of firms.

3.2 Overview of the Trends in the Demand for Education

Let us now examine now the general trends in the data. The overall level of education in the 209 firms of our sample is described by an index, constructed from the shares of employees with degrees of different educational level. These shares are weighted with wage differences[2]. Using wages as weights arises from the assumption prevalent in

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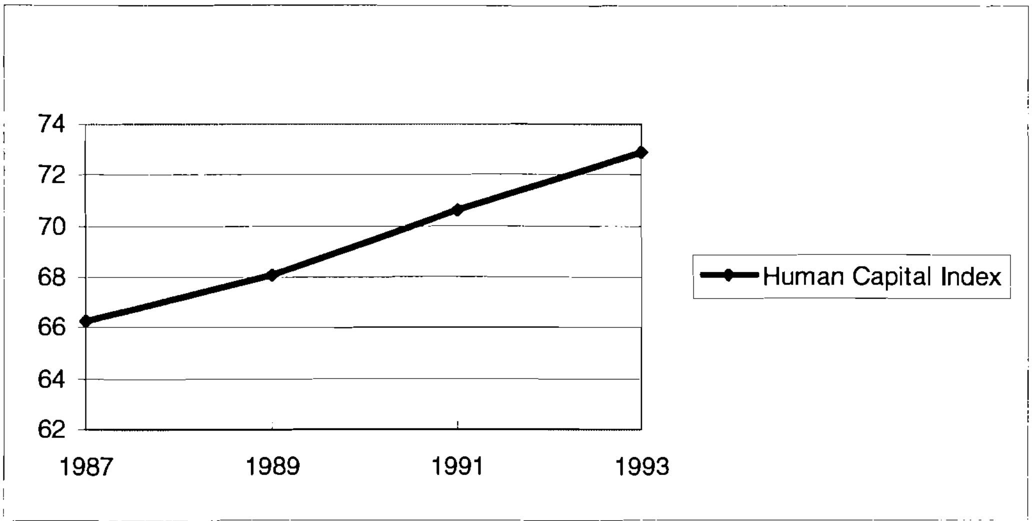
[1] National statistical office

[2] The HC-index is constructed in the following way: $H = \frac{(h_2 w_2 + h_3 w_3 + h_4 w_4)}{w_1}$, where h_i denotes the share of employees with the level of education i running from 1 = basic education to 4 = post-graduate (doctoral or licenciate) degree, and w_i denotes the corresponding average wage in the firm. So the index is the sum of the shares of employees with more than basic education, weighted by the wage difference with respect to the basic wage.

human capital theories that marginal productivity of labor is reflected in wage. I use the firm-specific wage levels, which should improve the accuracy of the indicator.

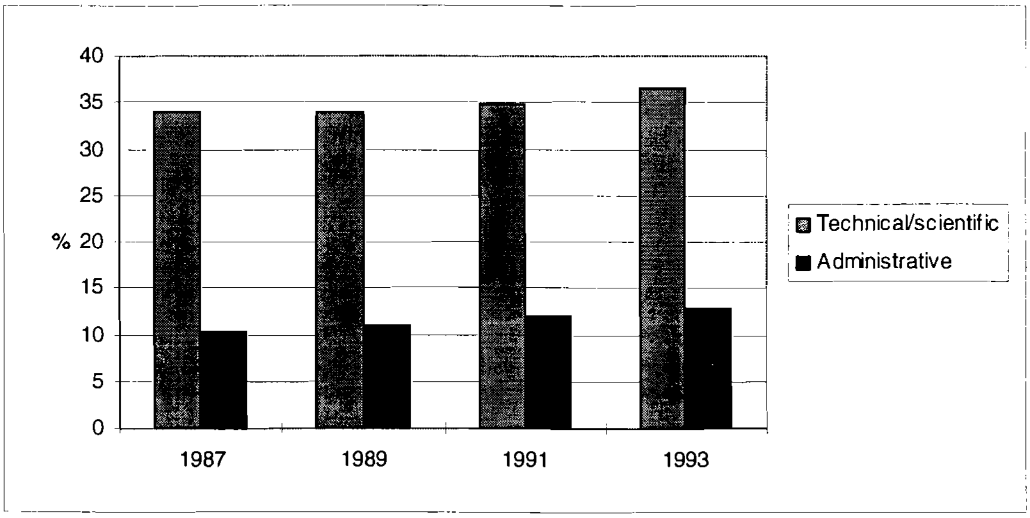
However, the human capital theoretic idea about the wage equaling marginal productivity has been frequently criticized. It is based on the assumption of perfect labor markets, and, more importantly, it does not take into account the dynamic learning effects. Notwithstanding these, I expect the human capital index to be a general indicator of the stock of educational competences, which is needed in comparing the total stocks in different firms.

Figure 3.1 Trends in the general educational stock (N=209)



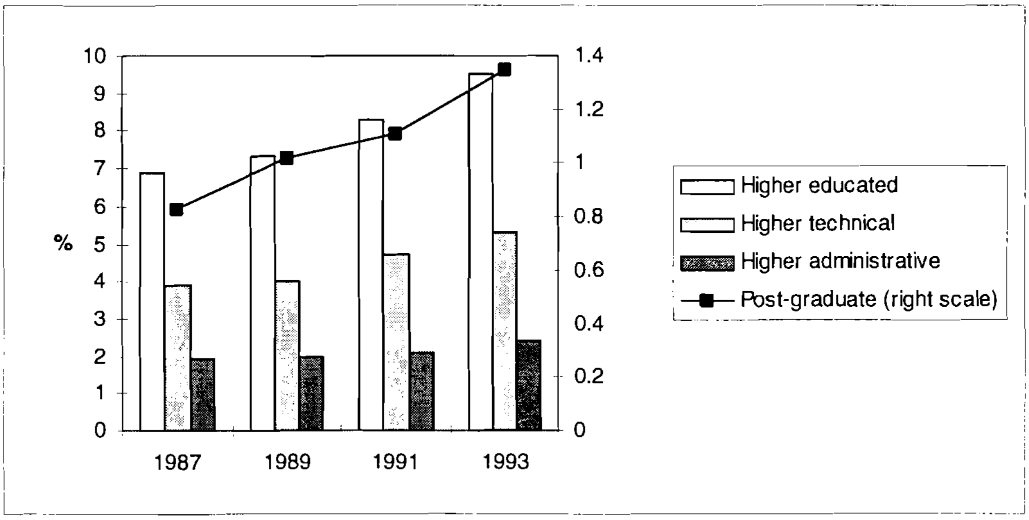
As shown in figure 3.1, the general level of education has continued to rise steadily from 1987 to 1993. There may be two reasons for this rather rapid growth in just six years. On the one hand, in accordance with another study about a sample of Finnish large manufacturing firms (Leiponen 1995), there is a general trend of rising levels of education in Finnish manufacturing industry. On the other hand, in the period of study that coincides with the severe depression in the economy, the firms may have cut down the number of the less educated production workers more rapidly than that of the highly educated white-collar workers.

Figure 3.2 Broad fields of education



The share of employees with a technical or natural scientific degree has continued to rise (figure 3.2), although not as strikingly as in a previous study on large corporations (ibid.). Also the share of employees with an "administrative" degree (in a commercial, social, law or administrative field) has risen modestly.

Figure 3.3 Employees with a higher education degree

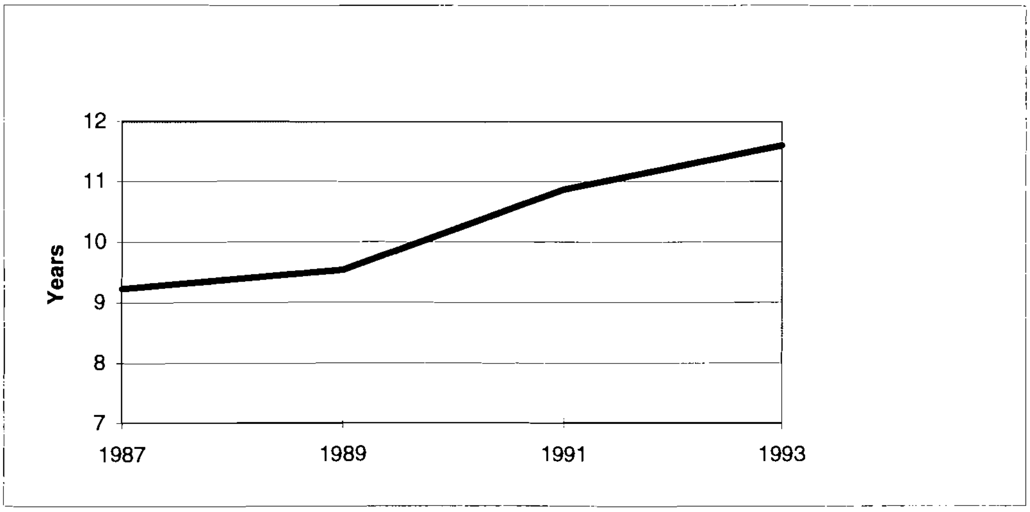


In figure 3.3 it is apparent that the share of employees with higher education has grown rapidly, from 6.9% to 9.5%. A considerable part of this change can be attributed to technical and natural scientific fields of education. The share of employees with higher technical or natural scientific degree grew from 3.9% to 5.3%. Finnish manufacturing firms are typically very engineering oriented, and this tendency seems to have further intensified.

The number of employees with a post-graduate degree was rising swiftly as well (in total 63% over the six years). In spite of this, there were in 1993 still only 1.4 post-graduates per firm on average. However, as the number of employees with a post-graduate degree reflects the research skills in the firm to some extent, it shows that the firms on average have not cut down their research activities during the hard times of the turn of the decade, instead they have long-sightedly allocated more resources to these activities.

Average tenure, which measures the firm-specific experience accumulation, has increased between 1987 and 1993. A likely explanation, in addition to the natural experience accumulation in a constant set of firms, is again the general economic environment: possibilities to recruit new employees have been limited in most companies. This can be seen in particular in the steeper rise between 1989 and 1991, coinciding with the most difficult period.

Figure 3.4 Average tenure



4 Educational Competences and Tenure by Industry

I now turn to investigate sectoral differences in the patterns of acquiring competences through education and firm-specific work experience. As already discussed in the introduction, I expect industries to differ in terms of demand for education. The rate and nature of changes in the technological and competitive environment determine to a large extent the need for education of different levels and fields. Moreover, the rate of change influences the need for new types of competences and skills, which is reflected in the average years of tenure.

These external factors are common to firms operating in the same industry. In addition, firms have some degrees of freedom in choosing how technology or knowledge intensive activities they intend to carry out. Therefore, there are both industry and firm level factors at work. In this section I will concentrate on the former.

The demand for educated employees is substantially higher in R&D intensive industries. R&D expenditure was more than 3% of the turnover in 1987 in electronics, machine, oil refining and chemical industries. As we observe in figure 4.1, the overall educational level is higher than average in all industries in these sectors. In particular, employees in electronics industry are very highly educated.

The capital intensive industries (defined by the capital/output ratio) have a general level of education close to the average, except base metal industry (figure 4.2). In base metals the level is lower, and it even seems to have declined between 1991 and 1993.

Figure 4.1 Human capital index in R&D intensive industries

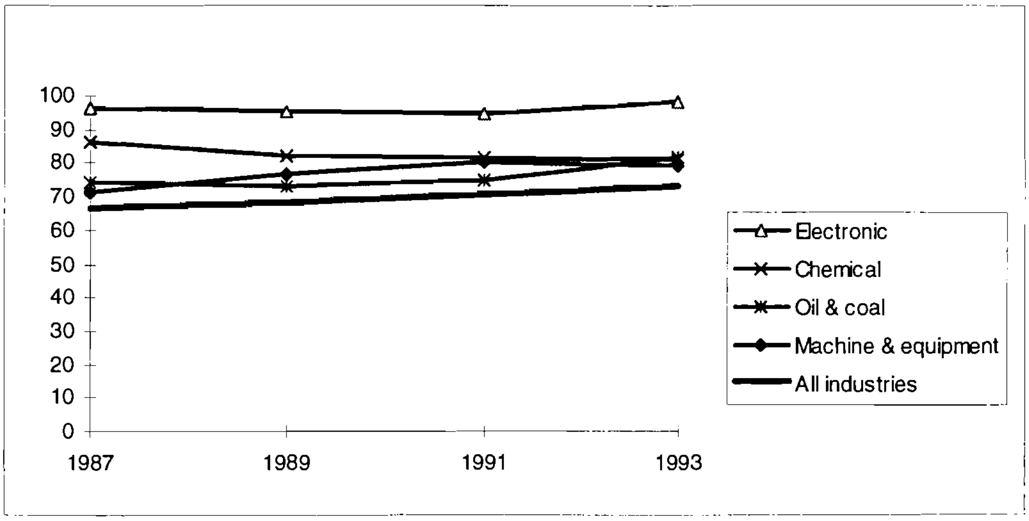
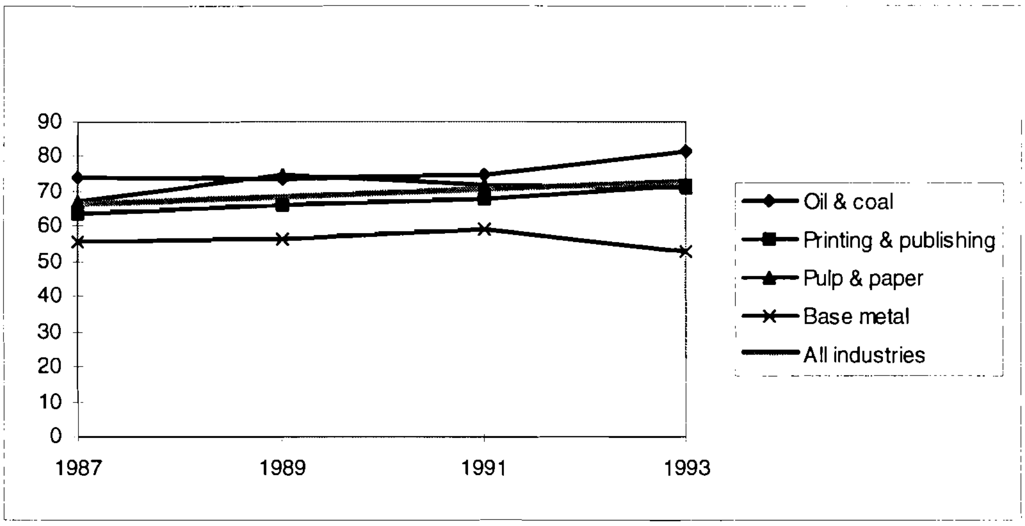


Figure 4.2 HC-index in capital intensive industries



In other industries the general levels of education tend to be slightly below the average of all sectors (figure 4.3). Only metal products industry is clearly above the average.

Especially the higher technical or natural scientific skills are - for obvious reasons - demanded in technology intensive industries (figure 4.4). There the electronics industry stands out again on a level of its own. Its share of employees with a higher education degree in the technical fields is more than three times the average in manufacturing industries.

Figure 4.3 HC-index in other industries

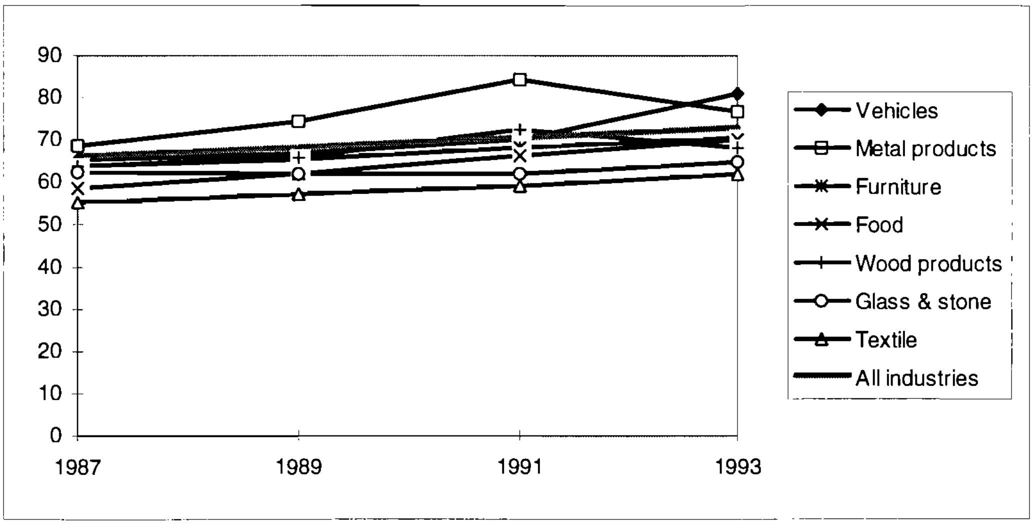
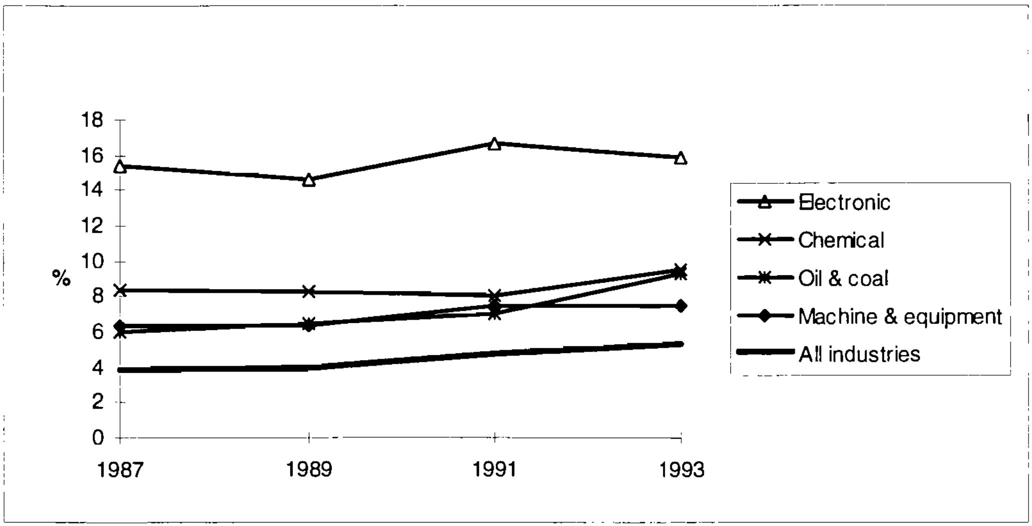


Figure 4.4 Higher technical/scientific skills in R&D intensive industries



Instead, the capital intensive sectors are more diversified with respect to demand for higher technical/scientific skills (figure 4.5). Oil and coal industry is on a significantly higher level, and has increased it clearly towards 1993. On the contrary, printing and publishing, in spite of being capital intensive, has a very low share of highly educated technical employees. This reflects assumably the slow pace of technological dynamics in the sector.

Figure 4.5 Higher technical/scientific skills in capital intensive industries

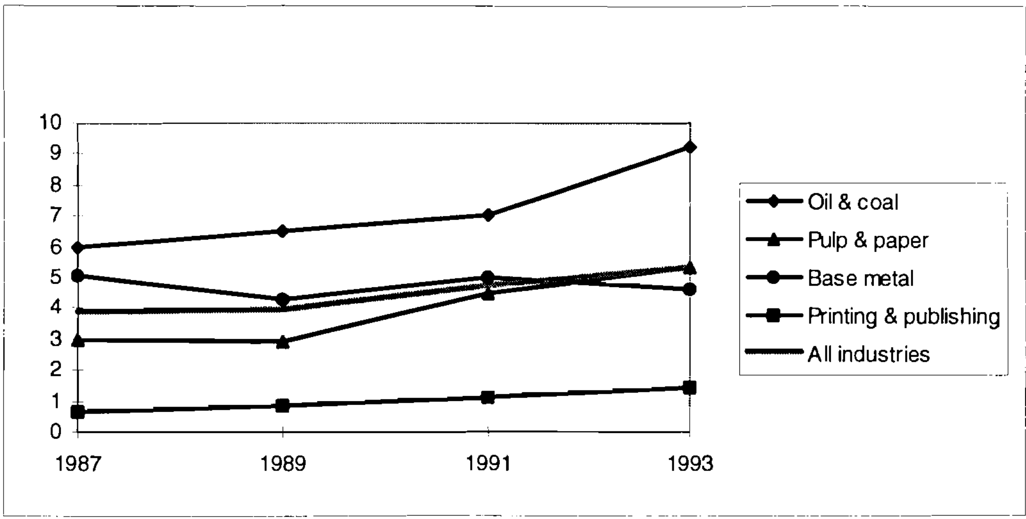
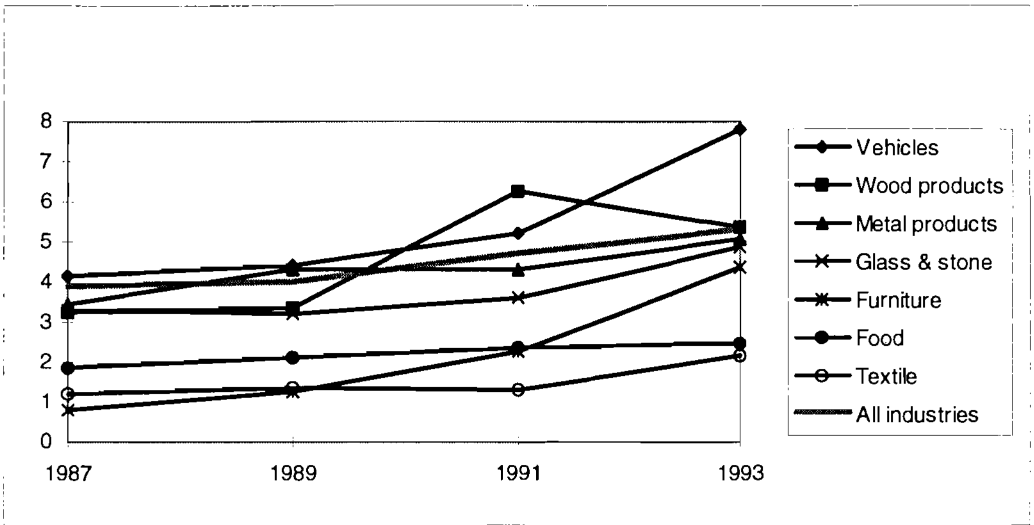
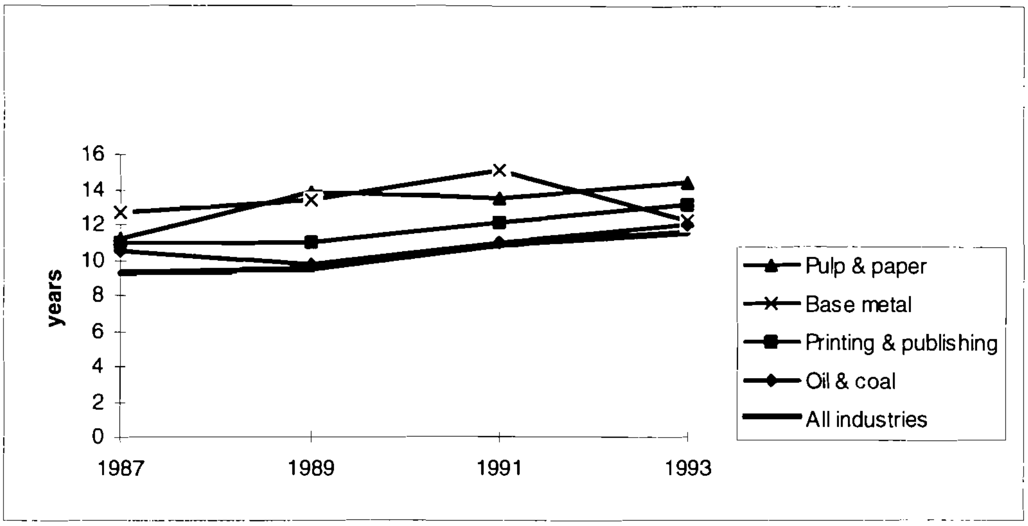


Figure 4.6 Higher technical/scientific skills in other industries



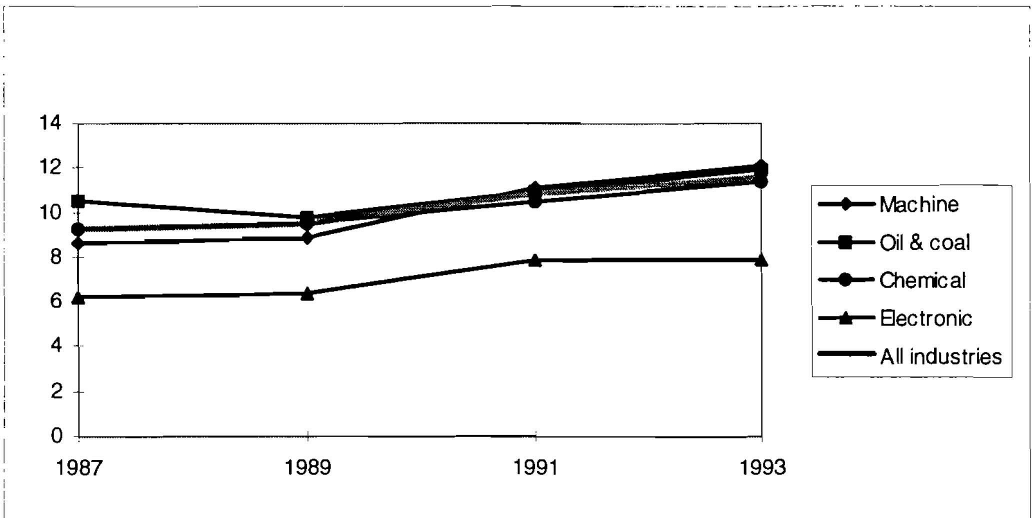
Other industries feature quite large diversity of technical intensity, as figure 4.6 above shows. Motor vehicles industry has inreased it very rapidly, almost doubling the share of higher technical employees over the period. On the other hand, food and textile industries do not, understandably, need very much this kind of skills. Surprisingly, furniture manufacturing has become considerably more intensive in higher technical skills.

Figure 4.7 Average tenure in capital intensive industries



In capital intensive industries, the accumulation of knowledge through learning on the job seems to be important (figure 4.7). The average tenure in capital intensive sectors, base metal, oil, printing and publishing, and paper industries, is somewhat higher than on average. In capital intensive industries the rate of technical change is probably slower because heavy investment in physical capital creates long term commitments. Therefore there is no need for bringing in people with new types of skills and knowedge, either. The evolution of employment in these industries has been quite smooth, except for the base metal industry, which appears either to have gone through a generational shift in 1991 and 1993, or else there has been a marked change in the employment policies.

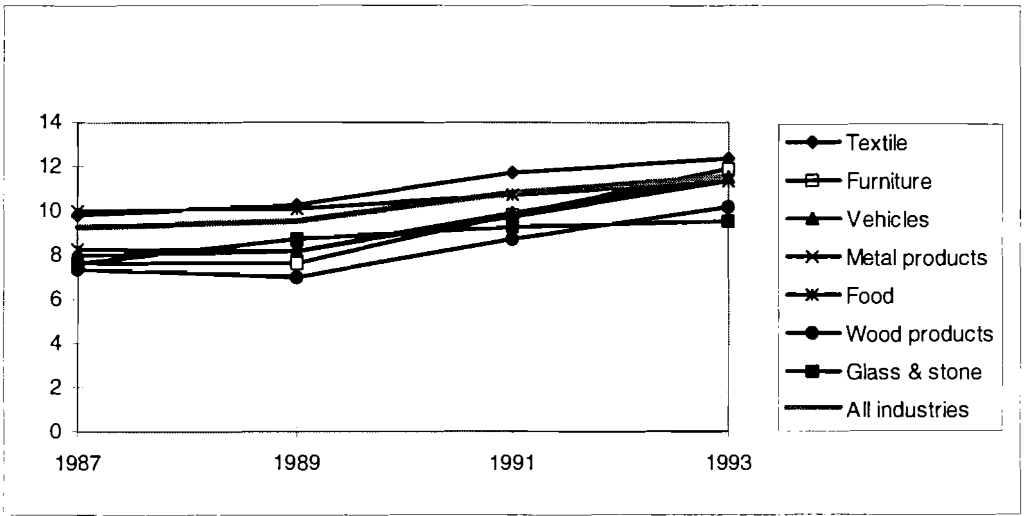
Figure 4.8 Average tenure in R&D-intensive industries



Electronics industry differs drastically from other industries also in terms of average length of employment presumably reflecting technological and market dynamics. This may be due to two reasons, the employee turnover may be very large, or the firms may have grown rapidly and recruited a considerable number of new employees. As a result, the average tenure remains around seven years.

In other industries than capital or R&D-intensive ones there cannot be found any significant differences from the average pattern of tenure (figure 4.9).

Figure 4.9 Average tenure in other industries



5 Innovators vs. Non-innovators

In this section I study how the innovating firms differ from the non-innovating ones. First some general differences concerning economic background variables, education, wages and tenure are traced. Later I investigate the economic performance of innovators in comparison to the non-innovators, and finally apply principal component analysis to grasp the characteristics of innovating firms.

5.1 Economic Position, Education, Wages and Tenure

Table 5.1 presents some broad economic differences between different types of innovators ("Inn") and non-innovators ("Non"). The data consist of a cross-section of 333 firms. Product innovators are defined as firms that launched new products in the markets between 1989 and 1991. Process innovators are firms that significantly improved their production methods or introduced new ones, and product improvers are firms that significantly upgraded their products. Comprehensive innovators realized both product and process innovations between 1989-1991.

Table 5.1 Innovators vs. non-innovators: economic indicators

	Product Innovators		Process Innovators		Product improvements		Comprehensive Innovators	
	Inn	Non	Inn	Non	Inn	Non	Inn	Non
(N)	(175)	(158)	(181)	(152)	(197)	(136)	(116)	(217)
Sales (MFIM) 1991	265	366	489	104	456	106	317	312
Export share (%) 1991	27	19	26	20	28	17	29	20
Market share (%) 1991	0.99	0.85	1.22	0.56	1.2	0.52	1.0	0.88
Concentration ratio (%) 1991	24	19	22	21	24	18	24	20
Capital intensity 1991	0.15	0.16	0.16	0.15	0.15	0.16	0.15	0.16
Personnel 1987	382	242	407	207	408	183	444	247
Change in personnel 1987-1991	-20	-35	-27	-27	-38	-12	-39	-21

Process innovators and product improvers are larger than non-innovators, which is reflected in sales, personnel and market share. It is intriguing that product innovators are smaller than product non-innovators with respect to sales, but not personnel. Product innovating firms tend in general to be more labor intensive than non-innovators. Also comprehensive innovators are more labor intensive than non-innovators. However, we must bear in mind that this description does not take industry differences into account. Size, labor intensity and probability of making innovations may be confounded by the technological conditions in the industry.

Innovators export a larger part of their sales than non-innovators. This has partly to do with their larger size, it is easier for larger firms to find the resources needed in establishing foreign marketing channels. Part of the explanation may lie in their superior competitiveness thanks to innovation.

Innovating firms operate in slightly more concentrated industries than their non-innovating counterparts on average. Instead, there are no differences with respect to capital intensity.

All groups have cut down their labor force during the depression, but product innovators have reduced it relatively and absolutely less than other innovators, whereas product improvers have made most drastic labor cuts. Relatively the largest cuts were undertaken by product and process non-innovators.

Table 5.2 below clearly indicates that innovating firms employ more highly educated workers. Both the overall educational stock (HC-index), shares of higher education and higher technical/scientific education are consistently larger in innovating firms, although among the process innovators the difference is not so marked. Also the managers and the "upper staff" in innovative firms are more highly educated, and larger share of them has a technical or natural scientific education than their counterparts in non-innovating firms.

Table 5.2 Innovators vs. non-innovators: education

	Product Innovators		Process Innovators		Product improvements		Comprehensive Innovators	
	Inn	Non	Inn	Non	Inn	Non	Inn	Non
(N)	(175)	(158)	(181)	(152)	(197)	(136)	(116)	(217)
HC-index 1987	69	62	67	64	69	61	71	63
Share of higher education (%) 1987	8	5	7	6	8	5	8	6
Higher technical/ scientific degrees 1987 (%)	37	35	36	35	38	33	39	34
Share of post-graduates (%) 1987	0.19	0.25	0.28	0.07	0.26	0.08	0.22	0.21
Share of post-graduates (%) 1991	0.26	0.32	0.36	0.09	0.32	0.15	0.30	0.26
Number of post-graduates 1987	0.74	0.61	1.12	0.14	1.04	0.15	0.99	0.51
Managers with higher education (%) 1990	48	42	47	43	49	38	48	43
Share of upper staff with higher education 1990	80	74	78	76	80	73	80	76
Average years of tenure	8.0	8.3	8.3	8.1	8.2	8.1	8.3	8.1

Furthermore, innovating firms tend to be more research oriented, manifested in their tendency to employ more people with a post-graduate degree. Again, product innovation differs from other types of innovation. There the share of post-graduate degree employees is higher among the non-innovators, but in absolute terms the opposite is true. Interestingly, for process innovation and product improvement the difference between innovators and non-innovators is very clear with respect to the number and share of post-graduate degree employees, and the innovators have even further increased their research intensity compared to non-innovators, measured with this human resource. Hiring of scientists depends on a sufficient size of the firm, which may be related to indivisibilities in R&D activities. Presumably partly because of this, the smaller non-innovators and product innovators do not employ that many researchers, whereas the larger process innovators and product improvers employ them more than proportionally.

As regards average tenure, there cannot be found any clear differences between innovators and non-innovators.

5.2 Economic Performance of Innovating Firms

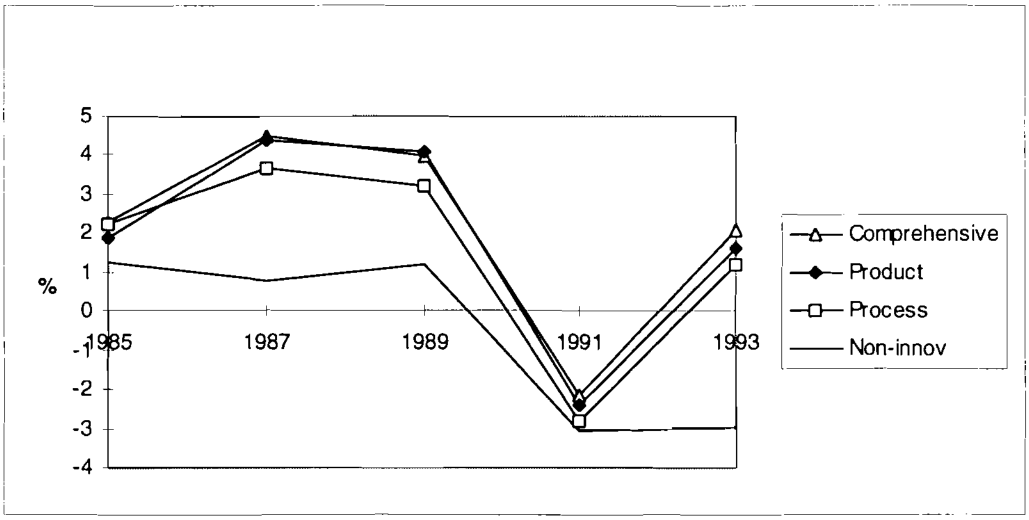
In this subsection I compare the economic performance of innovating firms with that of the non-innovating ones. Traditionally innovation has been viewed as a one-shot event, which creates a temporary monopoly position. Taking advantage of this position the firm may realize monopoly profits, but as information about the novelty diffuses, other firms imitate and compete away the "excess" profits. This point of view does not take knowledge accumulation into account, instead, any firm has equal chances of innovating just by investing in R&D.

However, it might be the case that innovation is less costly for some firms. Innovation requires different kinds of knowledge assets and capabilities, some of which may be acquired from the markets, some are inherently tacit or organizational. Therefore they have to be created through a slow and partly collective learning process. This organization-specific, strategic knowledge is one of the determinants of long run performance (cf. Teece and Pisano 1994).

It has been suggested, that innovation is a continuous process during which the firm accumulates more innovative capabilities (Geroski et al. 1993). As a result, innovations tend to cumulate in certain firms. Moreover, innovating firms are able to generate monopoly profits continuously, and they are more reactive and adaptive to changes in the environment. Thus they perform consistently better than non-innovators.

For the firms in the sample this seems to be the case as well. Figures 5.1 and 5.2 show the evolution of net profit margins and returns on capital invested in innovating and non-innovating firms. Here the sample consists of 209 firms. Non-innovators include firms that did not realize any kind of innovations. They were less profitable throughout the period of 1985-1993, both in terms of profit margins and rates of return on investment (ROI). Already in 1987 firms that realized product innovations in 1989-1991 were clearly more profitable. The innovators were better able to exploit the opportunities revealed during the boom of the late 1980s.

Figure 5.1 Profitability of innovation: net profit margin



Furthermore, with both measures of profitability the innovators were more flexible also in the sense that although the slump in early 90s was drastic indeed for both types of firms, innovators regained their previous level in just two years, measured with ROI, compared to the sluggish recovery of the non-innovators. Net profit margins did not recover completely in two years after the drop, but also there we can see that innovators were able to react more rapidly to the changed conditions. The faster recovery of ROI compared to the profit margins is probably due to the fact that ROI may be manipulated in the short run through financial operations.

Figure 5.2 Profitability of innovation: return on investment

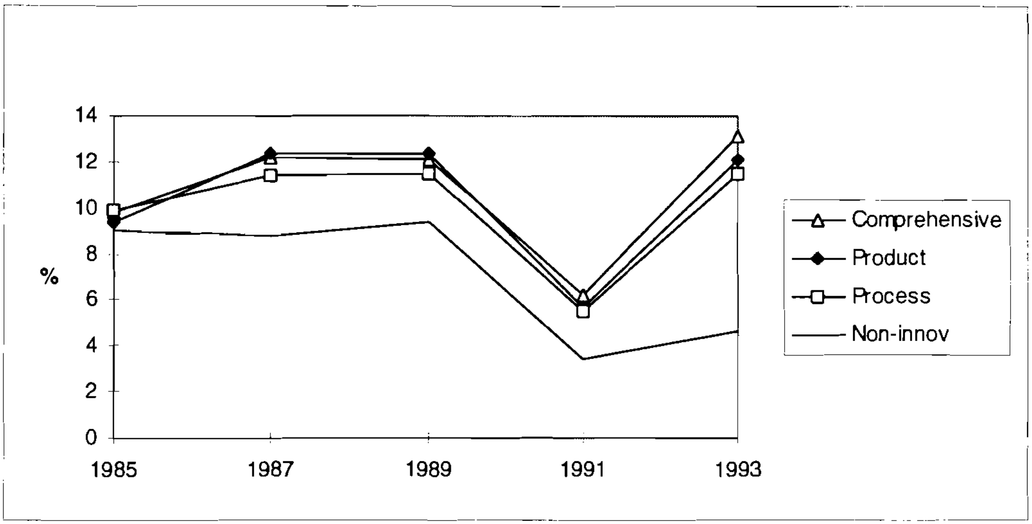


Figure 5.3 depicts the evolution of sales in these four groups of firms. Process innovators are the largest on average, and they also seem to have grown the fastest. Product and comprehensive innovators' growth performance is almost identical. These firms were somewhat hampered by the slump of the turn of the decade, while process innovators continued to grow throughout the period. Non-innovators are small firms, and they have not grown practically at all in real terms.

In terms of market share acquisition, product innovators appear to have performed the best, although all types of innovators have grown very slowly in this sense. Non-innovators have been not successful in conquering markets.

Figure 5.3 Growth of innovating firms: sales

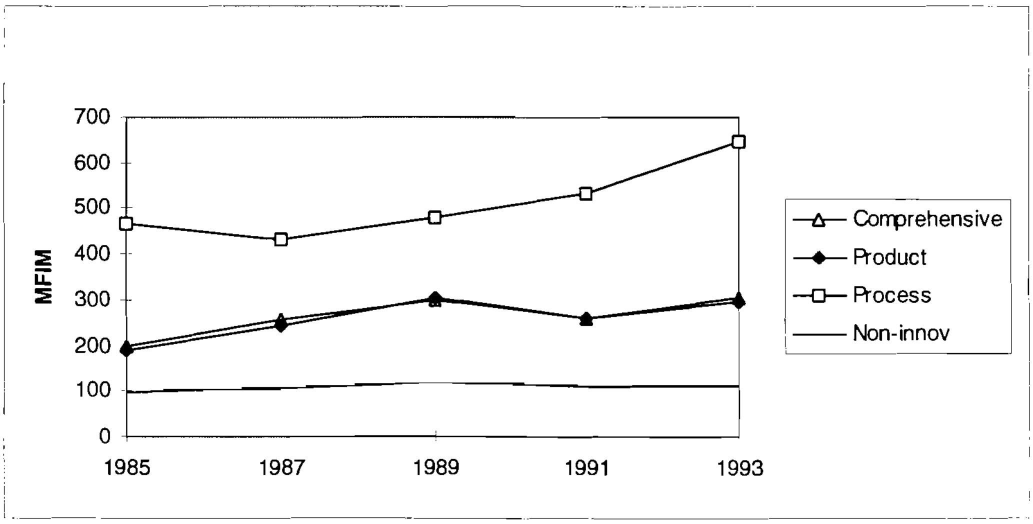
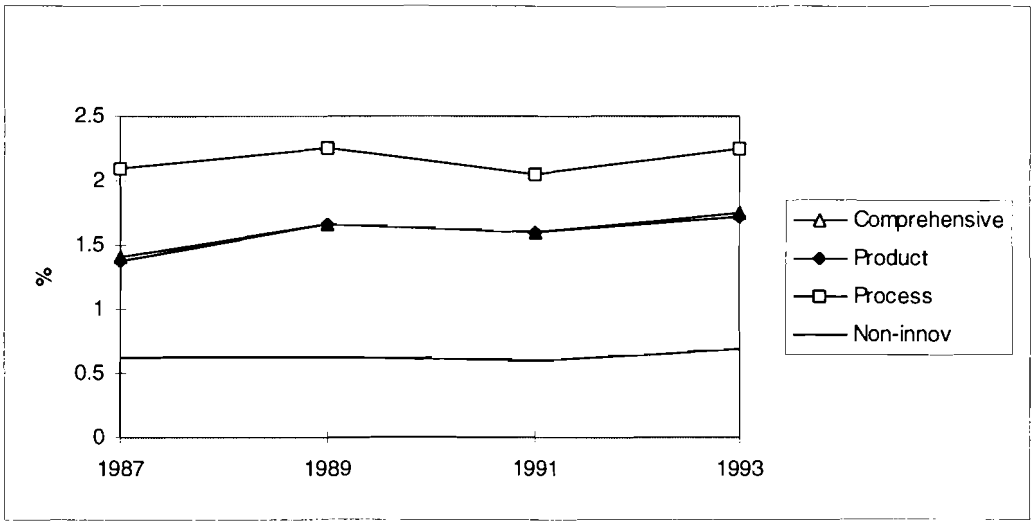


Figure 5.4 Growth of innovating firms: market share



5.3 Principal Components of Innovating Firms

Here I describe the types of firms that can be found in the data set through principal component analysis. I study how the typical firms among the product innovators differ from those among process innovators, and which attributes tend to go together. It is found that there are indeed specific types of firms in these two groups, and some types exist in both groups.

I use a set of variables including 10 competence related and 10 economic variables, which are described in table 5.3 below. The whole data set consists of a cross-section of 333 firms, and the values are for the year 1991 unless otherwise indicated. With six principal components about 2/3 of the variation is accounted for. This indicates that the overall variation is quite large.

Among the product innovators PRIN1 weights heavily (indicated by bold letters) general and technical education, and the firms scoring high in this component operate most often in an R&D intensive industry. PRIN2 depicts large low-tech firms, which rely on experience accumulation and labor cuts. The third most common firm type is a middle-sized firm that grows very labor-intensively, and does not accumulate general competences but work experience. In fact, the change in the share of employees with higher education is heavily negatively weighted. Instead, more employees with research competences are hired. PRIN4, explaining still about 8% of the variation, combines again the labor-intensive and research competence emphasizing growth patterns, now among firms operating in non-concentrated industries. Here the competence levels are quite low, but their growth gains some weight in the analysis. On the contrary, firms operating in very concentrated industries, described with PRIN5, are associated with an increasing share of higher educated, reflected also in wages, and orientation towards domestic markets. The last component considered here is dominated by capital intensive firms, that have quite wide a base of technical competences and acquire general competences rapidly.

Table 5.3 Variables

Variable	Definition
HC87	*Human Capital Index* (defined on p.7) 1987
HIGH87	Share of employees with higher education degree (%) 1987
POST87	Number of employees with post-graduate degree 1987
TECH87	Share of employees with technical or natural scientific degree (%) 1987
HITECH87	- " - higher technical or natural scientific degree (%)1987
ΔHC	Change in HC index over 1987-1991
ΔHIGH	Change in HIGH 1987-1991
ΔPOST	Change in POST 1987-1991
ΔTECH	Change in TECH 1987-1991
TEN87	Average tenure in the firm (years) 1987
SALES	Sales turnover (million FIM) (1985-1993)
EXPORT	Exports in proportion to sales (1989-1993)
MS	Market share (%)(1987-1993)
WAGE87	Average wage level in the firm 1987
ΔWAGE	Change in WAGE 1987-1991
L87	Labor force in the firm 1987
ΔL	Change in L 1987-1991
K-INT	Capital intensity (capital/output ratio) 1991
CON3	3 firm concentration ratio in the industry 1991
RD-INT	R&D intensity in the industry

The group of process innovators is dominated by large firms. The two most common types are competence-intensive firms in R&D intensive businesses, and secondly low-competence and high-experience firms in low-tech industries. The differences in competence levels between these two are quite pronounced. However, both types employ researchers, as this tends to go with the size. Technology and competence intensive firms are also more likely to export than the firms in low-tech businesses. PRIN3 emphasizes again labor-intensive growth, associated with decreasing general competence level, but growth of technical competences. With respect to PRIN4 the high scoring firms include non-capital intensive firms in non-concentrated industries, which acquire higher educated people at a fast rate, and in which the average tenure is very low due to this significant turnover of labor. Higher education is quite directly reflected in the wage level, which lends support to many studies using wage levels as a proxy for human capital. In this data set at least a high wage level is clearly associated with a large share of employees with higher education. The last component weights heavily firms in concentrated low-tech industries, having rather low competence levels, but investing with a considerable rate in higher educated employees. This component coincides to a significant extent with the PRIN5 of product innovators.

Table 5.4 Product innovators' principal components (N=175)

Eigenvectors	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6
HC87	**0.40**	-0.11	-0.08	-0.11	0.07	-0.14
KORK87	**0.46**	-0.03	0.12	-0.06	0.05	-0.11
TKORK87	**0.46**	-0.09	0.04	-0.04	0.04	-0.04
TUTK87	0.22	0.38	-0.09	0.10	-0.10	-0.05
TEKN87	**0.30**	-0.17	-0.21	-0.08	-0.16	**0.33**
KOKE87	-0.06	0.26	**0.31**	-0.27	0.12	0.18
DHC	-0.08	0.01	-0.25	0.23	0.02	**0.49**
DKORK	-0.02	0.04	**-0.40**	0.18	**0.49**	-0.09
DTEKN	-0.12	-0.02	0.12	0.18	0.26	-0.21
DTUTK	0.12	-0.07	**0.40**	**0.49**	0.12	0.14
SALES	0.11	**0.41**	0.13	0.28	0.01	0.03
EXPORT	0.17	-0.04	-0.09	0.15	**-0.30**	0.09
MS	0.04	**0.45**	0.04	0.17	-0.13	-0.09
WAGE87	0.26	0.11	0.25	-0.24	**0.32**	-0.07
ΔWAGE	0.07	0.06	**-0.38**	0.18	**0.49**	-0.04
L87	0.10	**0.49**	-0.04	0.03	-0.05	0.07
ΔL	0.03	-0.29	**0.39**	**0.40**	0.13	0.11
K-INT	0.00	0.10	0.04	-0.11	0.15	**0.64**
RD-INT	**0.33**	-0.12	-0.15	0.12	-0.08	0.13
CON3	0.00	0.02	0.15	**-0.35**	**0.36**	0.22
Proportion	19.4 %	17.1 %	10.1 %	7.7 %	6.9 %	6.2 %
Cumulative	19.4 %	36.5 %	46.6 %	54.3 %	61.2 %	67.4 %

The upshot from the preceding discussion is, that the competences associated most often with product and process innovation differ in some respects. Technical competences are more emphasized with the product innovation. With both kinds of innovation there emerges a low-tech and low-competence firm profile, weighting heavily accumulated experience. Another type common for both innovation groups is one with rapid labor-intensive growth, actually associated with a decreasing level of higher education. I also identify a type for firms in very concentrated industries, associated with increasing employment of higher educated people and oriented towards domestic markets.

Table 5.5 Process innovators' principal components (N=181)

Eigenvectors	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6
HC87	**0.30**	**-0.32**	-0.16	0.07	-0.05	0.20
KORK87	**0.35**	-0.26	-0.01	-0.07	0.24	0.09
TKORK87	**0.34**	**-0.30**	-0.03	0.00	0.19	0.02
TUTK87	**0.36**	**0.31**	-0.02	0.07	-0.08	-0.12
TEKN87	0.20	-0.27	-0.16	0.04	-0.06	-0.23
KOKE87	0.02	0.21	-0.08	**-0.51**	0.11	0.11
DHC	-0.11	0.21	0.03	0.15	**0.52**	-0.21
DKORK	-0.02	0.09	-0.24	**0.48**	0.14	0.28
DTEKN	-0.07	0.10	0.21	0.10	**0.61**	-0.14
DTUTK	0.21	0.04	**0.53**	0.07	-0.06	0.15
SALES	**0.33**	**0.34**	0.13	0.10	-0.13	-0.04
EXPORT	0.11	-0.14	-0.08	0.07	0.12	**-0.57**
MS	**0.32**	**0.37**	0.08	0.08	-0.12	-0.07
WAGE87	0.25	-0.02	-0.05	**-0.30**	**0.39**	0.23
ΔWAGE	0.06	0.04	-0.20	**0.50**	0.09	**0.33**
L87	0.27	**0.33**	-0.23	-0.06	-0.02	-0.09
ΔL	0.04	-0.15	**0.63**	0.04	0.02	0.14
K-INT	0.00	0.06	-0.16	-0.24	0.06	0.02
RD-INT	0.26	-0.22	0.03	0.07	-0.06	**-0.23**
CON3	0.09	0.06	-0.10	-0.20	0.07	**0.35**
Proportion	21.6 %	16.6 %	9.3 %	8.8 %	7.5 %	6.4 %
Cumulative	21.6 %	38.2 %	47.5 %	56.3 %	63.8 %	70.2 %

6 Conclusions

In this descriptive study I have unveiled some patterns of accumulating educational competences in manufacturing firms, and how these relate to other characteristics of the firm and industry in question. I discovered significant differences among industries, as was expected. The rate of technological change and capital intensity have an important bearing on the types of skills and capabilities needed, and also on the *rate* with which new capabilities are demanded. In technology intensive industries the levels of education, in particular technical education, tend to be higher and average tenure lower than in other industries. Instead, in capital intensive industries the long-term commitments do not necessitate a fast renewal of the competence base via employee turnover.

The comparison of innovating and non-innovating firms raised some interesting issues. Innovators tend to have a higher level of all kinds of educational competences, compared to non-innovators. In terms of economic performance, the data indicate the obvious result that innovators tend to be more successful in terms of profitability, exports, as well as growth.

Innovators are also larger than non-innovating firms. Firm size appears to be quite an important indicator of the type of innovative activity the firm is likely to undertake. Product innovators are the smallest, quite close to them in size and other attributes too are comprehensive innovators, which make both product and process innovations. Gradual improvements in products and processes, on the other hand, are more likely in large firms. This lends support to the proposition by Cohen and Klepper (1996) that the share of process innovation in all R&D tends to increase with size, because of spreading the innovating costs over a larger output.

The relationship between size and the type of innovative activity can also be viewed through the product life cycle hypothesis (Klepper 1996). According to our results, product innovators are more labor intensive, and endowed with high general and in particular technical capabilities. Technical and research skills are also increased with quite a fast rate. Comprehensive innovators are slightly larger than product innovators, and they also have a high level of education. Comprehensive innovators are still relatively labor intensive, but the intensity has started to decrease rapidly, presumably thanks to process innovation. Firms involved in gradual improvement of their products are also characterized by significant labor cuts. Finally, process innovators are the largest firms measured with sales. Their labor intensity has decreased significantly due to gradual improvement of products and processes. They continue to invest in research competences, although the rate of acquiring other types of educational competences, notably higher technical capabilities, seems to slow down.

Non-innovating firms, they are smaller and less successful. They perform badly throughout the period of study, and there does not seem to be a way out of stagnating performance without innovation.

Thus, according to this study, "good" characteristics tend to cumulate in the same firms, which refers to complementarities between investments in human resources and technology, for instance. Accumulation of knowledge through learning supports innovation, technological change and eventully economic performance. Competences acquired in education seem to have a significant role in this process. However, more explicit research into the fundamental factors of innovativeness would be required to understand the initial driving force of this co-evolution of capabilities with certain strategies and economic performance.

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