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Education, Tenure and Innovation in Manufacturing Firms

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Keskusteluaiheita - Discussion papers

No. 561

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EDUCATION, TENURE AND INNOVATION IN MANUFACTURING FIRMS

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LEIPONEN, Aija, EDUCATION, TENURE AND INNOVATION IN MANUFACTURING FIRMS. Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1996, 26 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781- 6847; no. 561).

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 competencies. 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 product life cycle hypothesis, which emphasizes the size of the firm as a determinant of i.a. 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 competencies. Comprehensive innovators, i.e. firms carrying out both product and process innovation remind in many respects of 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 competencies than general or technical skills.

KEY WORDS: education, innovation, profitability of firms, product life cycle

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TIIVISTELMÄ: Tässä tutkimuksessa kuvataan suomalaisten teollisuusyritysten koulutustasoa ja työkokemusvarantoa. Erityisesti tarkastellaan näiden yhteyksiä yritysten innovaatiotoimintaan. Koulutustaso yrityksissä nousi melko nopeasti 1987-93, varsinkin teknisen tai luonnontieteellisen koulutuksen saaneita sekä tutkijakoulutettuja palkattiin lisää yrityksiin. Toimialoittaiset erot ovat kuitenkin huomattavia. Teknologiaintensiivisillä aloilla koulutustaso on korkea, erityisesti teknisen koulutuksen osalta. Pääomaintensiivisillä aloilla sen sijaan keskimääräinen työsuhteen kesto on pitkä ja koulutustaso matalampi.

Verrattaessa innovatiivisia ja ei-innovatiivisia yrityksiä huomataan, että innovoivien koulutustaso on selvästi korkeampi ja kannattavuus parempi. Taloudellinen menestys saattaa johtua innovoivien yritysten suuremmasta joustavuudesta. Tähän viittaa se, että 1990-luvun alun lamasta innovoivat yritykset ovat palautuneet paljon nopeammin kuin ei-innovoivat.

Yrityksiä luonnehditaan myös pääkomponenttianalyysin avulla. Tulokset tukevat elinkaari-teorioita, joiden mukaan mm. innovaatiotoiminnan suuntautuminen riippuu olennaisesti yrityksen koosta. Ei-innovoivat yritykset ovat pieniä ja menestyvät huonosti. Tuoteinnovoijat ovat hieman isompia ja varsinkin työvoimaintensiivisiä. Niiden yleinen ja tekninen koulutustaso on korkea ja edelleen kasvussa. Yleisinnovaattorit, yritykset jotka tekevät sekä tuote- että prosessi-innovaatioita, muistuttavat monessa suhteessa tuoteinnovoijia. Ne ovat kuitenkin hieman suurempia ja niiden työvoimaintensiivisyys on matalampi. Prosessi-innovoivat yritykset ovat puolestaan selvästi suurimpia, niiden työvoimaintensiivisyys on matalin, ja ne perustavat toimintansa enemmän tutkijakoulutettujen osaamiseen kuin yleiseen tai tekniseen osaamiseen.

ASIASANAT: koulutus, innovaatiot, yritysten kannattavuus, tuotteen elinkaari

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Yhteenveto - Finnish summary

Tutkimuksessa kuvataan suomalaisten teollisuusyritysten koulutus- ja työkokemusvarantoja ja niiden kehitystä 1987-1993. Varsinkin koulutuksen ja innovaatioiden yhteyksiä selvitetään. Taustamotivaationa työlle on inhimillistä pääomaa korostava ns. uusi kasvuteoria. Teoriat nojautuvat inhimilliseen osaamiseen teknologisen kehityksen ja talouskasvun moottorina mutta eivät pohdi mitä osaaminen on, minkälaisia tietoja ja taitoja taloudessa tarvitaan ja miten osaamiseen kannattaisi investoida.

Kasvututkimuksissa inhimillistä pääomaa kuvataan useimmiten juuri koulutustason avulla. Useissa selvityksissä on kuitenkin havaittu, että koulutustaso, ei sen kasvu (koulutusinvestointien suuruus), korreloi talouskasvun kanssa. Koulutuksen vaikutukset näkyvät siis merkittävien viiveiden jälkeen, ja vaikutuksiin saattaa liittyä skaalautuja. Nämä voivat johtua tiedon leviämisestä sekä oppimisen ja innovoinnin sosialisesta luonteesta. Yksilöiden osaaminen vaikuttaa yhteisön - kansantalouden tai yrityksen - menestymiseen koko organisaation toiminnan kautta. Organisatorinen oppiminen ja kehittyminen puolestaan ovat hitaita prosesseja. Lisäksi osaaminen ja teknologia täydentävät toisiaan, samoin kuin erityyppiset osaamiset. Koulutus saattaa edistää teknologista kehitystä tarjoamalla oppimisen ja innovoinnin mahdollistavia perustietoja ja -taitoja.

Tutkimus perustuu Tilastokeskuksen kokoamaan aineistoon, joka yhdistää työssäkäyntitilastosta saatavia koulutustietoja vuoden 1991 innovaatiokyselyyn ja yritysten tilinpäätöstilastoon. Näin voidaan muodostaa 209 yrityksen aikasarjat sekä poikkeileikkaus 333 yritykselle. Tässä yrityskohtaisessa aineistossa on siten tietoja yritysten koulutustasoista ja -aloista 1987-93, vuosina 1989-91 tehdyistä innovaatioista sekä taloudellisesta kehityksestä 1985-93.

Yleinen koulutustaso on noussut aineiston yrityksissä suhteellisen nopeasti. Varsinkin teknisen tai luonnontieteellisen korkeakoulutuksen saaneiden osuus on kasvanut nopeasti, samoin tutkijakoulutettujen osuus ja määrä. Toimialoittaiset erot ovat kuitenkin huomattavia johtuen erityisesti teknologisen kehityksen luonteesta, mikä määrittelee koulutuksen kysynnän suurelta osin. Teknologiaintensiivisillä aloilla yleinen koulutustaso on korkeampi, teknisen korkeakoulutuksen saaneita on enemmän, ja työsuhteiden keskimääräinen pituus on lyhyempi, mikä viittaa uusien tietojen ja taitojen jatkuvaan tarpeeseen. Varsinkin elektroniikkateollisuudessa nämä ominaisuudet korostuvat. Pääomaintensiivisillä aloilla sen sijaan teknologian kehitys on hitaampaa, työsuhteiden kesto pidempi ja koulutustaso alempi.

Innovaatioita tehneiden yritysten vertailu muihin paljastaa, että innovatiivisten yritysten koulutustaso on korkeampi lähes kaikkien mittareiden suhteen. Tutkijoiden osuus prosessien ja tuotteiden vähittäisten parantajien keskuudessa on sen sijaan hyvin selvästi ei-innovoijia korkeampi. Innovoivat yritykset suuntautuvat enemmän vientiin. Lisäksi ne ovat ei-innovoivia suurempia markkinaosuudella ja henkilökunnalla arvioituna. Mielenkiintoista on, että tuoteinnovaatioita tehneet ovat ei-innovoijia suurempia henkilöstöllä mutta pienempiä liikevaihdolla mitattuna, eli ne ovat selvästi työvoimaintensiivisempiä. Yleisinnovoivat yritykset eli ne jotka tekivät sekä

tuote- että prosessi-innovaatioita, ovat hieman tuoteinnovoijia suurempia, hieman vähemmän työvoimaintensiivisiä, mutta muuten hyvin samankaltaisia. Tuoteparannuksia tehneet yritykset ovat edelleen suurempia, ja prosessi-innoivineet ovat suurimpia ja vähiten työvoimaa liikevaihtoa kohden käyttäviä. Tämä näyttää tukevan tuotteen elinkaari-teorioita, joiden mukaan yrityksen koko ja ikä määrittelevät suurelta osin tutkimus- ja kehitystoiminnan jakautumisen tuotteiden ja prosessien kehittämiseen. Prosessi-innovointi tulee kannattavammaksi koon myötä, sillä innovaation kasvavia skaalatuottoja voidaan hyödyntää laajemman organisaation sisällä.

Taloudellinen menestys on ollut innovoivissa yrityksissä parempi. Niiden kannattavuus on jatkuvasti parempi, ja erityisesti nähdään, että vuoden 1991 laman jälkeen ne ovat toipuneet huomattavasti nopeammin entiselle kannattavuustasolle, kun taas ei-innoivivat yritykset olivat vielä 1993 selvästi 1980-luvun tason alapuolella. Liikevaihdon kasvun suhteen prosessi-innoivijat näyttävät menestyneen parhaiten. Myös tuote- ja yleisinnovoijat ovat kasvaneet (reaalisesti) jonkin verran 1985-93, mutta ei-innoivivat yritykset eivät juuri kasva. Innovoiminen on siten yrityksen kasvun ja kannattavuuden edellytys. Karkeasti ottaen näyttää siltä, että menestyvät yritykset tulevat markkinoille tuoteinnovaation turvin, kasvaessaan ne alkavat tehdä myös vähittäisiä parannuksia tuotteisiin ja tuotantoprosesseihin, kunnes tuotteen markkinat alkavat kypsyä ja yritykset alkavat kilpailla enemmän hinnalla kuin uusilla tuoteominaisuuksilla.

The economic importance of knowledge and competencies is often stressed in the economic and political debate, but little 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 issues like incentives and contracting. However, we argue that because knowledge is a fundamental ingredient in the evolution of firms, these problems should not prevent the analysis of its implications.

Competencies 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 one industry. 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 are far more crucial. These *dynamic competencies* (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 competencies generate a process of accumulating organizational knowledge. We suggest here that the measurable aspects of competencies, in this case 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.

We make 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 measures, and standard firm and industry control variables. This type of a data set has not been much utilized in firm-level analyses.

The paper is organized in the following way. In section 2 we briefly discuss the existing literature on human capital and competencies in relation to technological change.

Section 3 characterizes the trends in the levels and fields of education and the average tenure in the sample of Finnish manufacturing firms over the period of study, 1987-1993. In section 4 the industry-specific differences in demand for competencies 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 several models of endogenous growth (e.g. Romer 1990) has been that technical change is a function of the stock of human capital. The next question we should 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 the growth of firms using firm level data (Leiponen 1995). Despite some obvious econometric problems of this type of regression analyses (e.g. endogeneity of explanatory variables), the upshot is that countries and firms that have a more educated work force tend to grow faster.

The theoretical framework behind these growth studies implies that the more human capital the faster the growth. However, the relationship cannot be all that simple in reality. Therefore it is of vital importance to ponder what kind of human capital is economically relevant in which activities, and 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 *investment 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 competencies in a team, and on the other, between competencies, 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 Competencies

A central issue with respect to the performance of economic organizations is the way they accumulate competencies. 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 own 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 in terms of 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 1989). R&D is therefore an important source of learning opportunities.

Knowledge is accumulated also in more inconspicuous ways through learning. While producing the firm learns about technology, competitors and customers, which enables it to improve its operating procedures. Learning about the firm's own competencies 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 available opportunities, the exploiting of which calls for innovation. Swift reaction and adaptation are essential for survival under rapid change of the environment.

It has been argued at least ever since Schumpeter (1942), that the incentive to do R&D and try to 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: 13). The long run competition is therefore about striving for successful R&D. Even being a successful 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.

If we focus on the role of knowledge in firm performance and evolution, innovation can be viewed as a process that transforms the internal capabilities in firms (see 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.

2.3 Technological Change and the Demand for Competencies

There exist complementarities between technological change and competence accumulation. For instance, Young 1993 has identified a process of learning by doing, which is bounded by the state of technology. 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. Therefore the more rapid the technological change in the firm, the more educated workers are needed.

Learning effects related to each technological *vintage* are analyzed 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, competencies, 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 innovation in firms. We will use the term educational competencies to describe the skills and learning abilities that can be acquired via schooling. They represent only a small part of all 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 at least on the macro level, so it is relevant to incorporate it into the studies of firm performance. Hence we will here assess the role of education in the accumulation of knowledge, and the connections with the different patterns of technological change, measured with R&D or capital intensity and innovation.

3 The Data on Education and Tenure in Finnish Manufacturing Firms

We investigate here the levels of education and accumulated firm-specific experience in Finnish industrial firms. We acknowledge that these are only very limited indicators of the competencies available to the firm's operations. However, education may be an important factor in learning through which firm-specific competencies are accumulated. It expands the set of available learning directions, and it is also an important input in the innovation activities (Senker 1995). Therefore, with the level of education we may 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, in other words 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 introduced to meet the needs created by the new environment. However, we conjecture that in any industry or firm, too static a labor force leads to halting learning and a decrease in innovativeness and flexibility. There has to be novelty introduced also in the work force. 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

We make use of quite a unique firm-level database compiled by Statistics Finland¹. The educational data describe in detail the formal level attained and the field of education of workers in firms. This is supplemented with information about the 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 our sample operate in 15 different 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, we have to content ourselves with a cross-section of 333 firms (for the year 1991) and time-series of 209 firms (1987-93).

The period of analysis was very turbulent, as it coincides with the worst recession in Finland since the 1930s. Our 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 related to knowledge accumulation that we wish to grasp should operate in all kinds of firms.

3.2 Overview of the Trends in the Demand for Education

Let us now describe some 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 differences². Using wages as weights originates from the assumption prevalent in

¹ National statistical office

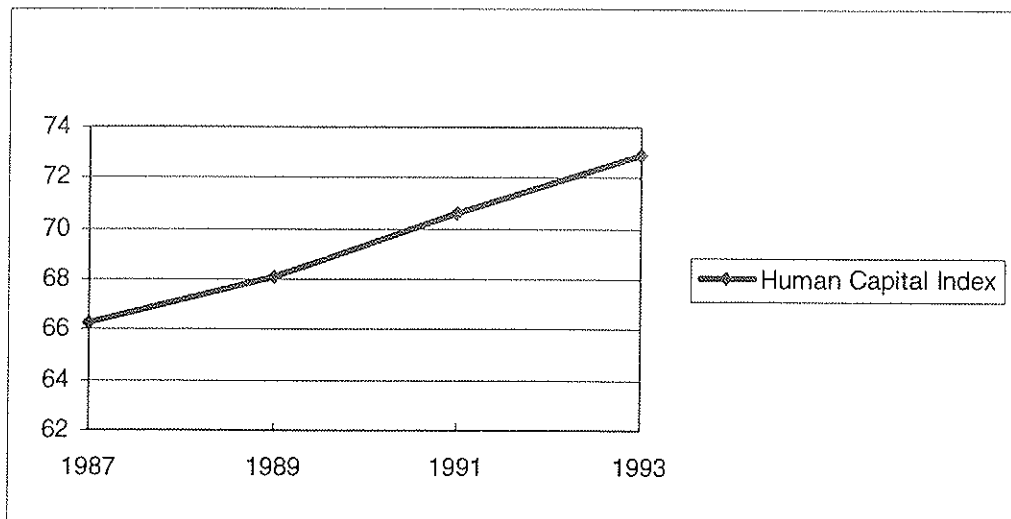
² The HC-index is constructed in the following way: $H = \frac{(h_2 w_2 + h_3 w_3 + h_4 w_4)}{w_1}$, where h_i denotes

the share of employees with the level of education i running from 1 = basic education to 4 = post-graduate (doctoral or licentiate) 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. We 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 frequently been 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, we expect the human capital index to be a general indicator of the stock of educational competencies, which we need in order to compare the total stocks in different firms.

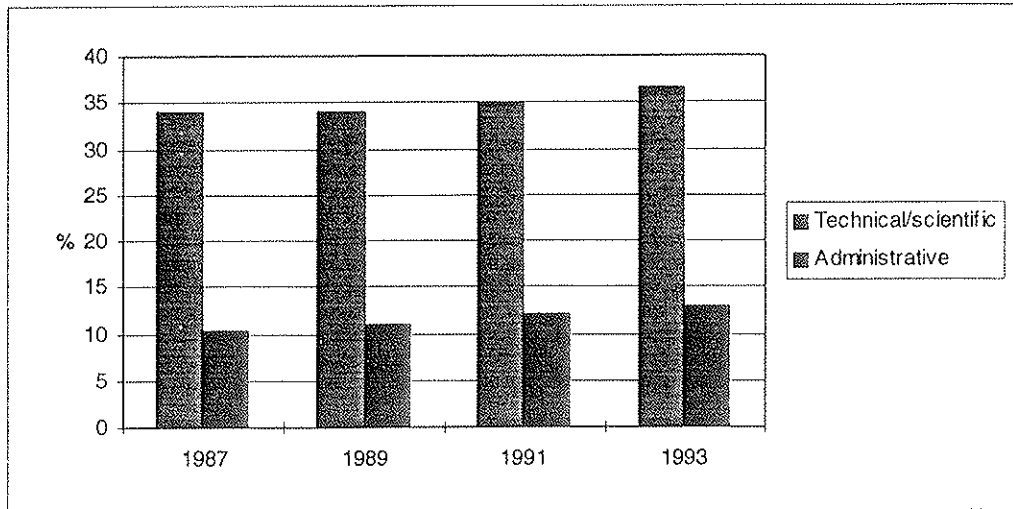
Figure 3.1 Trends in the general educational stock



As is 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 level of education in Finnish manufacturing industry. On the other hand, in the period of study that coincides with a severe depression in the Finnish 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.

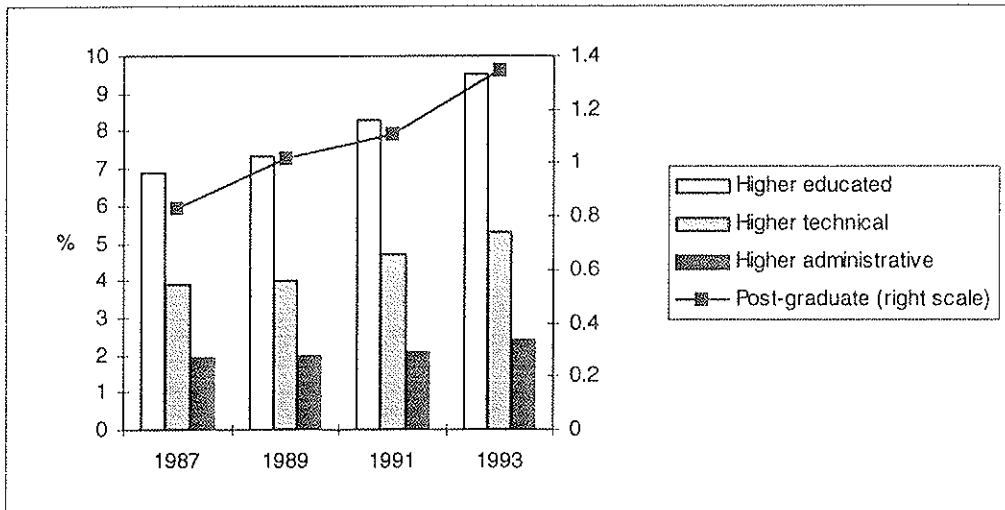
The share of employees with a technical or natural scientific degree has continued to increase (figure 3.2), although not as strikingly as in a previous study on large corporations (ibid.). Also the share of employees with an “administrative” degree (in a commercial, social, law or administrative field)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

Figure 3.2 Broad fields of education



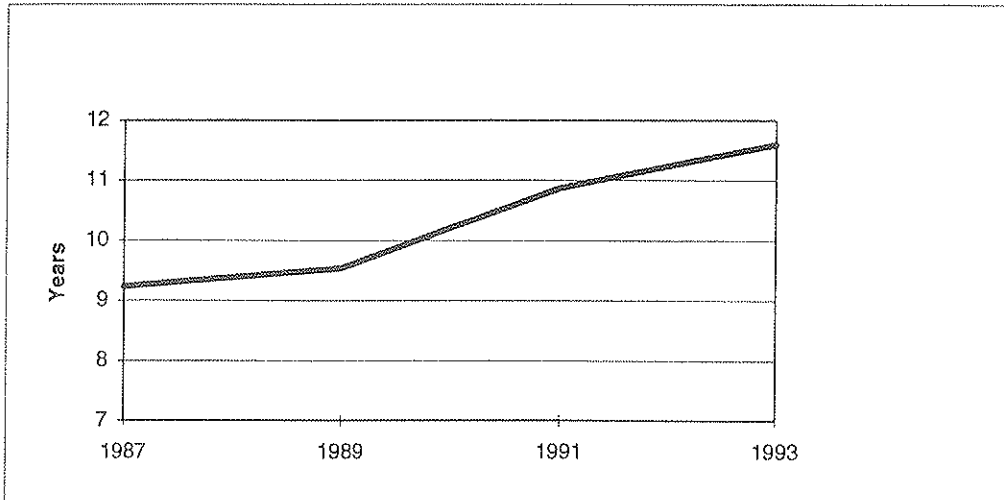
In figure 3.3 it is apparent that the share of employees with higher education (tertiary education: universities, colleges etc.) has grown very rapidly, from 6.9% to 9.5%. A considerable part of this change can be attributed to technical and natural scientific fields of education. The share of employees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

Figure 3.3 Employees with a higher education degree



The number of employees with a post-graduate degree was rising very rapidly (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.

Figure 3.4 Average tenure (N=209)



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.

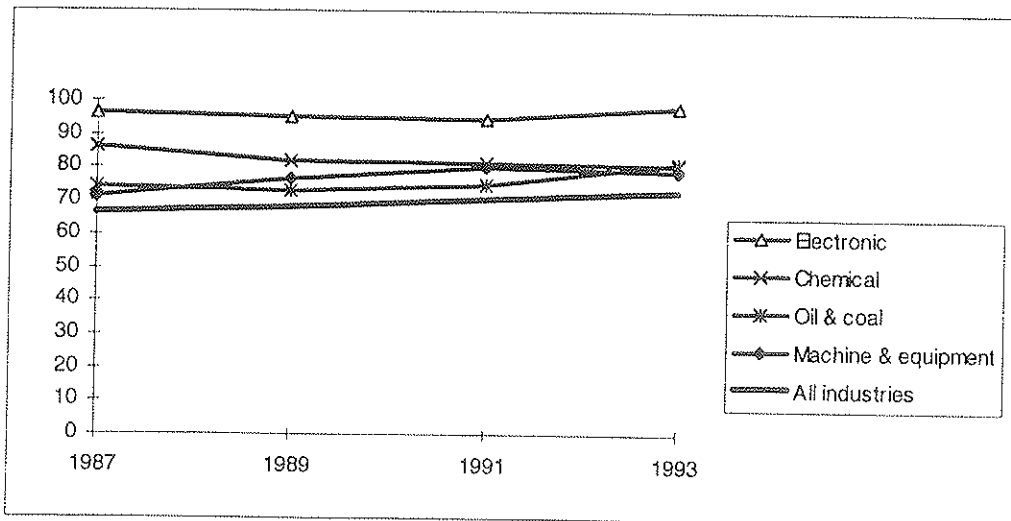
4 Educational Competencies and Tenure by Industry

We now turn to investigate sectoral differences in the patterns of acquiring competencies through education and firm-specific work experience. As already discussed in the introduction, we 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 competencies and skills, which is reflected in the average years of tenure.

These external factors are common to firms operating in the same market. 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 we 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 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.

Figure 4.1 Human capital index in R&D intensive industries



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 4.2 HC-index in capital intensive industries

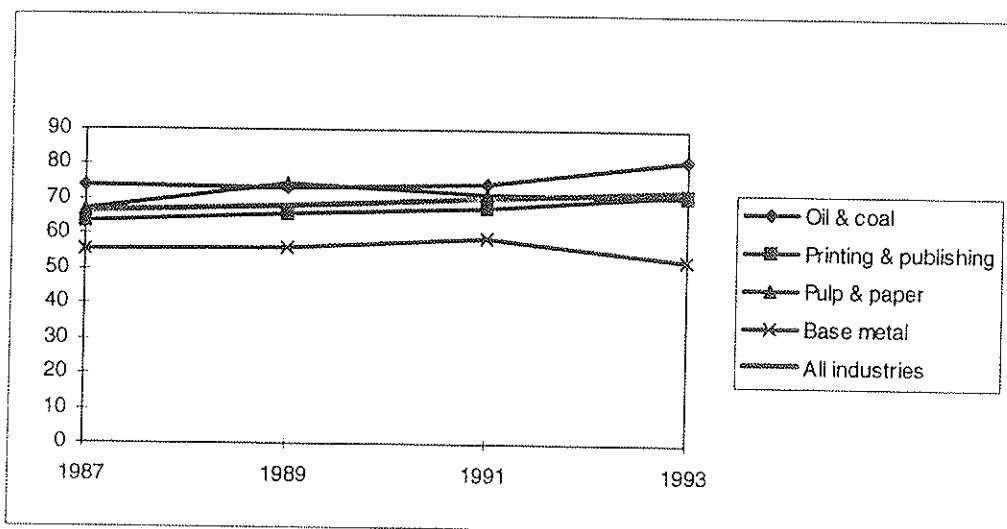
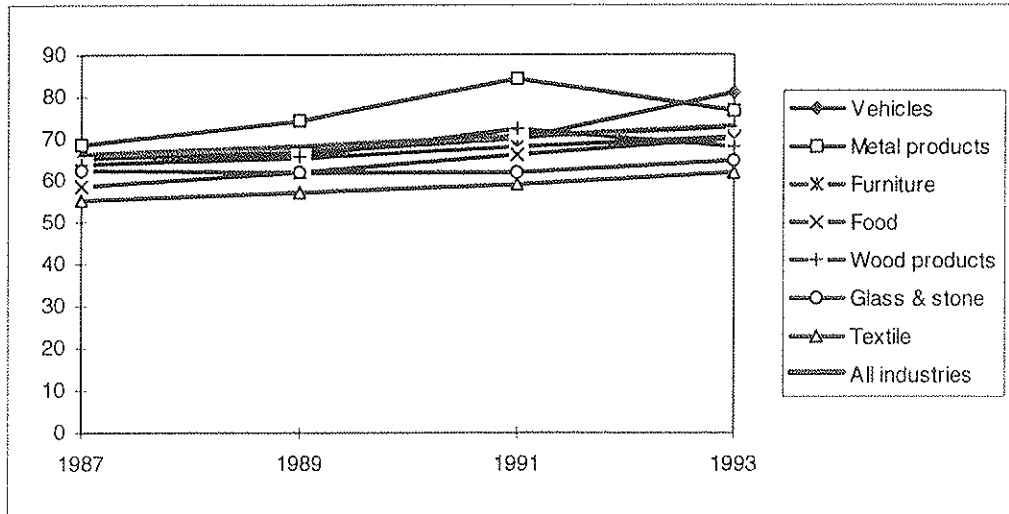


Figure 4.3 HC-index in other industries



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: The average share of employees with a higher education degree in the technical fields is more than three times the average in all industries.

Figure 4.4 Higher technical/scientific skills in R&D intensive industries (employees with higher technical or natural scientific degree in proportion to all employees)

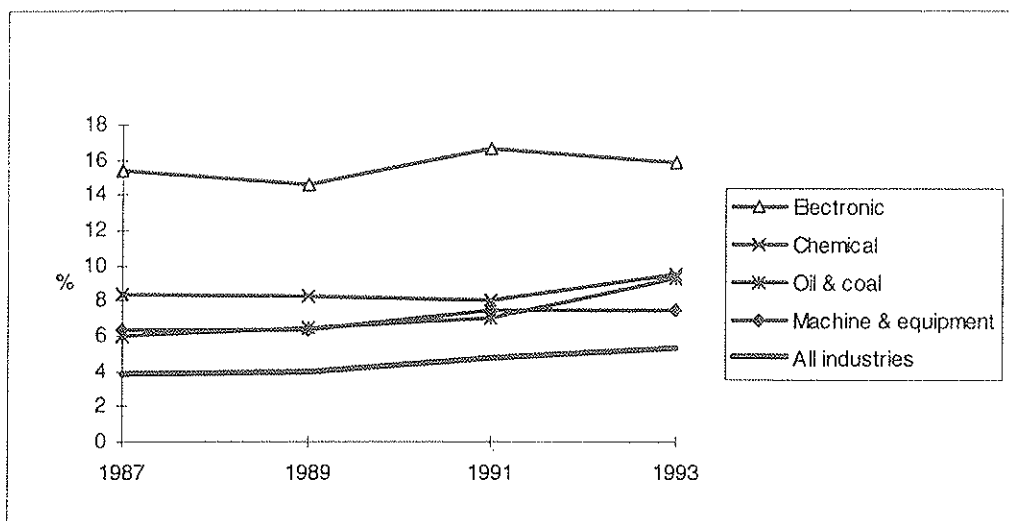
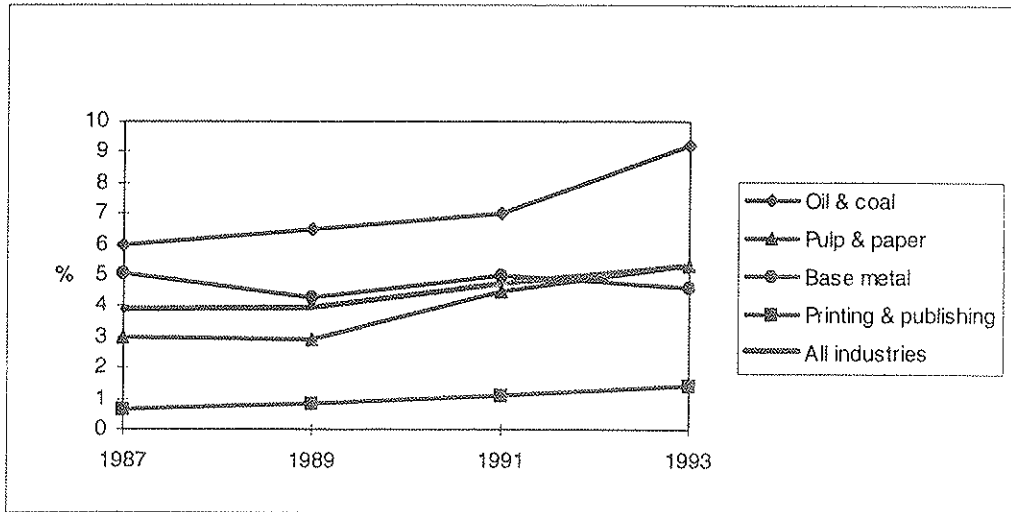
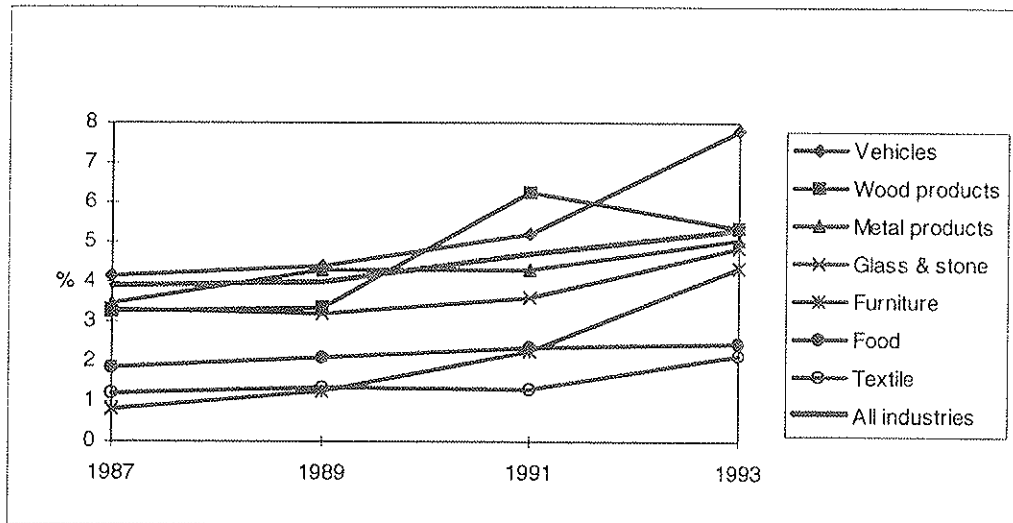


Figure 4.5 Higher technical/scientific skills in capital intensive industries



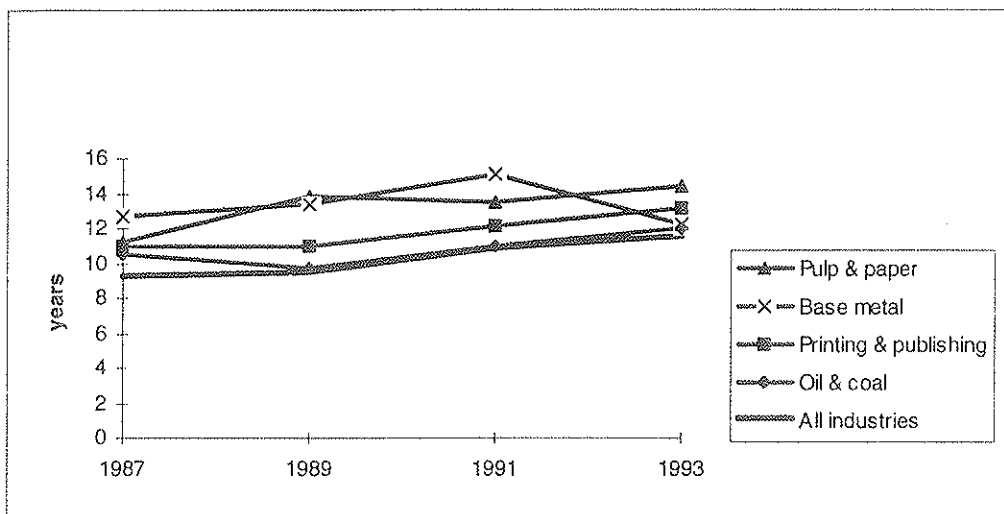
Instead, the capital intensive sectors are more diversified with respect to demand for higher technical/scientific skills (figure 4.5). Oil and coal industries are on a higher level, and have increased it clearly towards 1993. On the contrary, printing and publishing, despite it being a capital intensive activity, has a very low share of highly educated technical employees. This may reflect the slower pace of technological dynamics in the sector.

Figure 4.6 Higher technical/scientific skills in other industries



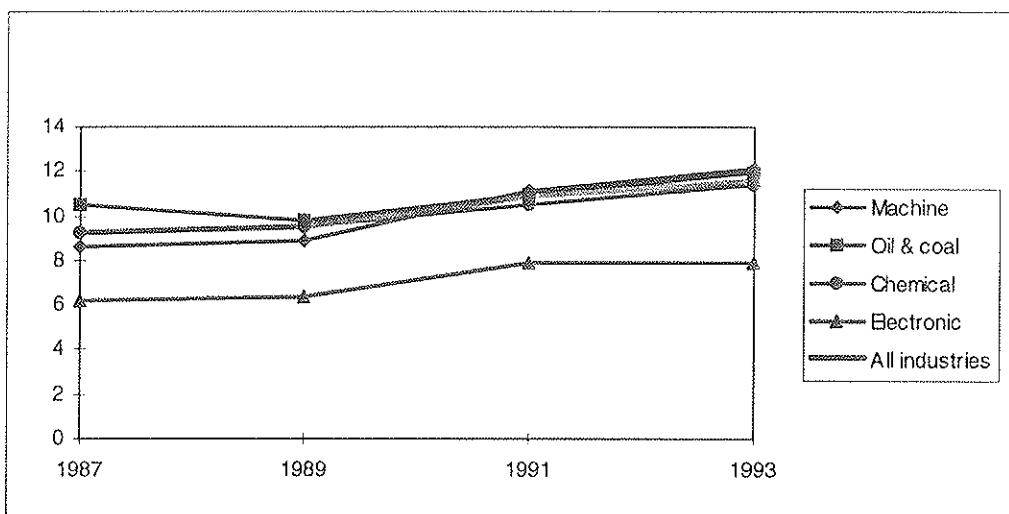
Other industries feature quite large variability of technical intensity, as figure 4.6 above shows. Motor vehicles industry has increased it very rapidly, almost doubling the share of higher technical employees over the period. On the other hand, food and textile industries do not, understandably, need very much of this kind of skills. Somewhat 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, possibly because skills needed are very firm-specific (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 than in other sectors 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 knowledge, 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

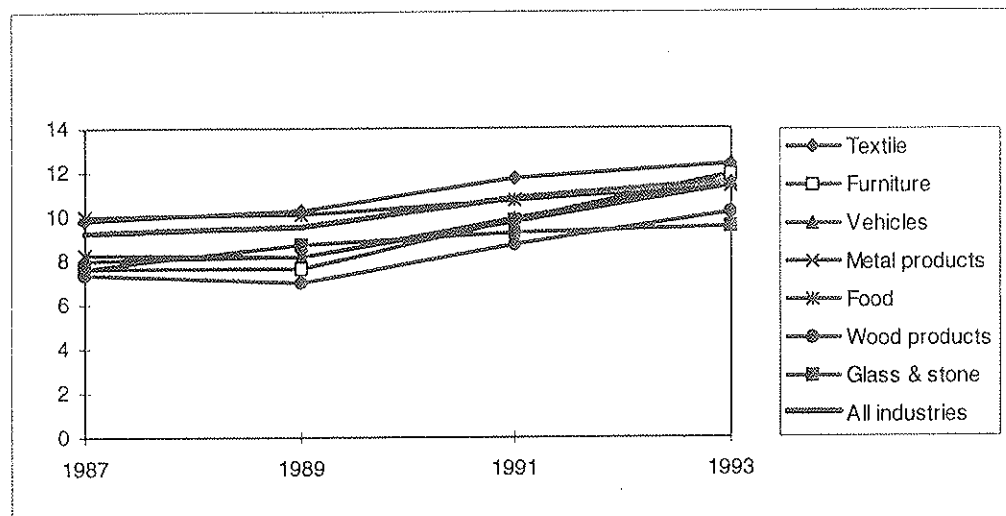


Electronics industry differs drastically from other industries also in terms of average length of employment. This may be due to two reasons, the employee turnover may be

very large, or the firms may have grown so fast and recruited such a considerable number of new employees, that the average tenure stays 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 we study how the innovating firms differ from the non-innovating ones. We first trace some general differences concerning economic background variables, education, wages and tenure. Later we 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

In table 5.1 there are presented some broad economic differences between different types of innovators and respective non-innovators. 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. So called comprehensive innovators realized both product and process innovations between 1989-1991. Non-innovators here refer to firms that did not realize these specific types of innovations, for instance a

product non-innovator did not create product innovations, but may have realized process innovations or product improvements.

Table 5.1 Innovators vs. non-innovators: economic indicators

(N)	Product Innovators		Process Innovators		Product improvements		Comprehensive Innovators	
	Inn (175)	Non (158)	Inn (181)	Non (152)	Inn (197)	Non (136)	Inn (116)	Non (217)
Sales (MFIM) 1991	265	366	489	104	456	106	317	312
Export share 1991 (exports/sales, %)	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 (market share of 3 largest, %)	24	19	22	21	24	18	24	20
Capital intensity 1991 (physical capital/sales)	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 if measured with sales, but not with personnel. This means that product innovating firms are in general significantly more labor intensive than non-innovators. Also comprehensive innovators are more labor intensive than non-innovators.

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. Nevertheless, 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 among them. Relatively the largest cuts were carried out by product improvement 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 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

(N)	Product Innovators		Process Innovators		Product improvements		Comprehensive Innovators	
	Inn (175)	Non (158)	Inn (181)	Non (152)	Inn (197)	Non (136)	Inn (116)	Non (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
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 are 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 actually the share of post-graduate degree employees is higher among the non-innovators. For process innovation and product improvement the difference between innovators and non-innovators is very clear with respect to the share of post-graduate degree employees. Partly this may be due to the fact that hiring post-graduate educated researchers depends on a sufficient size of the firm, which may be related to indivisibilities in R&D activities. Hence, the smaller non-innovators and product innovators do not employ too many researchers, whereas the larger process innovators and product improvers employ them more than proportionally. Another reason may be the different skill requirements of product and other types of innovation activities.

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 we 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 to some firms. Innovation requires many kinds of capabilities and competencies, some of which may be acquired from the labor market, but some are inherently tacit or organizational. Therefore they

have to be created through a slow and partly organizational learning process. This organization-specific aspect of the knowledge needed in innovation makes it a strategic determinant of long run performance.

It has been suggested (Geroski et al. 1993), that innovation is a continuous process which helps the firm to accumulate knowledge and capabilities. Being an innovator is then a generic characteristic of a firm, and for this reason innovations tend to be cumulated in some firms. Making new innovations is easier for firms that have innovated successfully previously, due to the accumulated internal capabilities. Firms that have the “habit” of doing innovations, are continuously able to generate monopoly profits. Moreover, they are more reactive and adaptive to changes in the environment. Thus they perform consistently better than non-innovators.

For the firms of our sample this seems to be the case as well. Figures 5.1 and 5.2 show the evolution of net profit margins and return on capital invested in innovating vs. non-innovating 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. 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.

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 the rates of return on capital invested than the profit margins is probably due to the fact that ROI may be manipulated in the short run through financial operations.

Figure 5.1 Profitability of innovation: net profit margin³

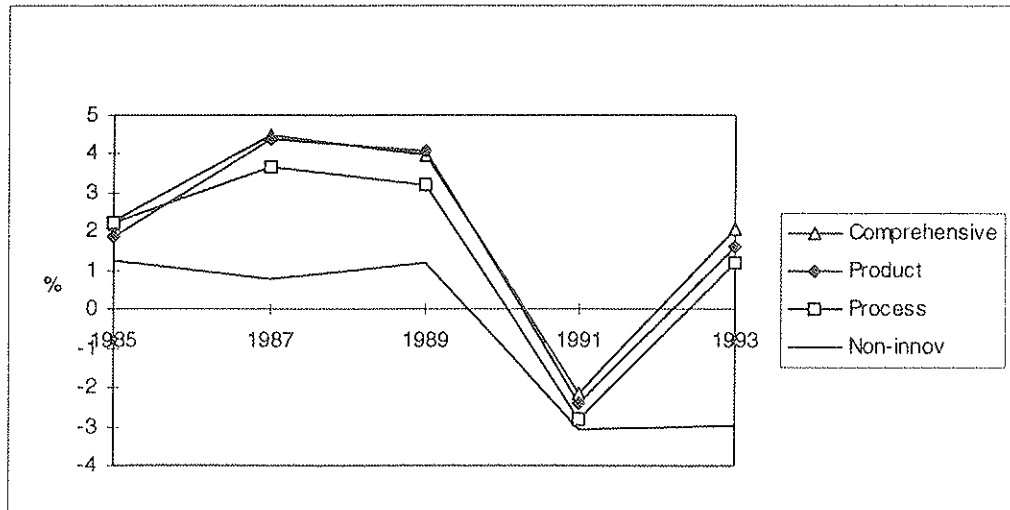


Figure 5.2 Profitability of innovation: return on investment

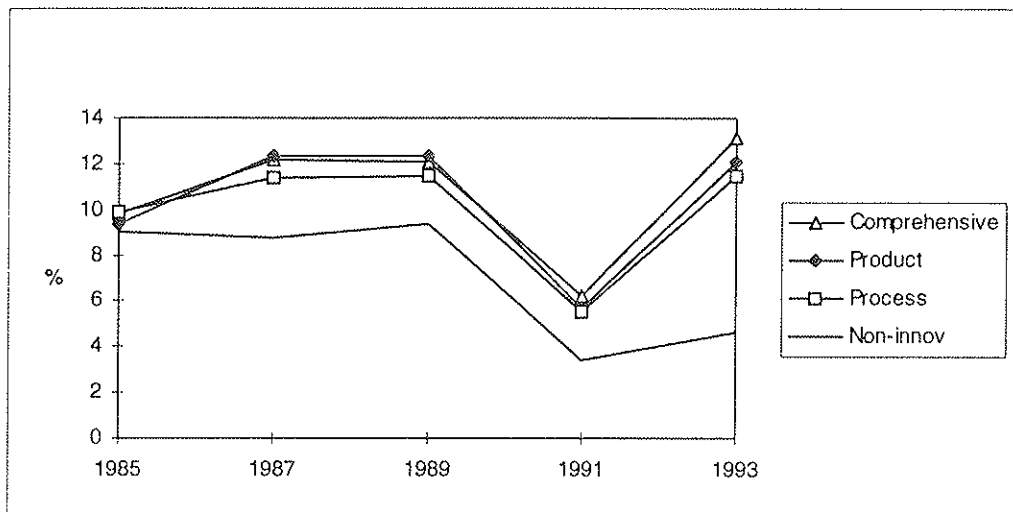


Figure 5.3 depicts the evolution of sales in these four groups of firms. Process innovators are the largest on average, and they also seem to have grown the fastest. Product and comprehensive innovators' growth performance is almost identical. These firms were somewhat hampered by the slump of the turn of the decade, while process innovators continued to grow throughout the period. Non-innovators are small firms, but 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 more markets.

³ The groups of product, process and comprehensive innovators are partially overlapping.

Figure 5.3 Growth of innovating firms: sales

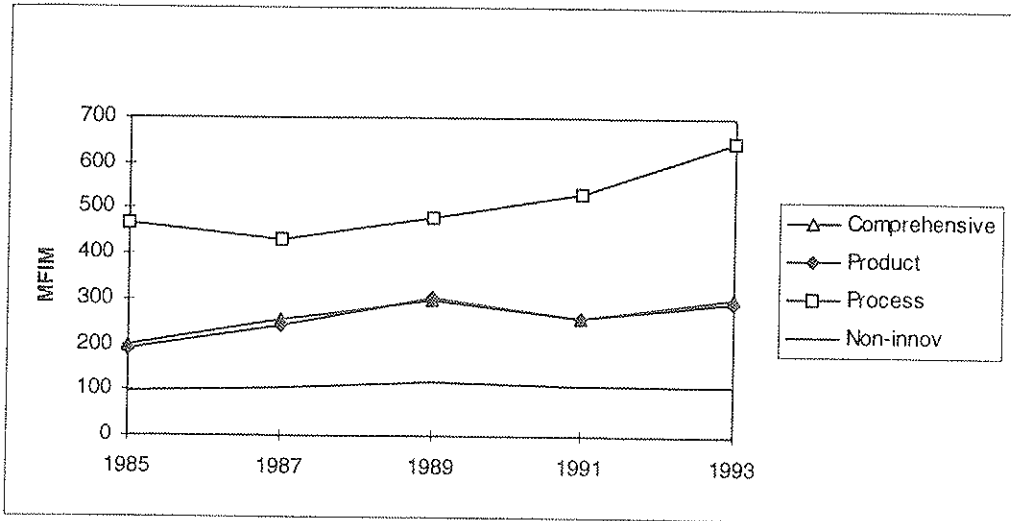
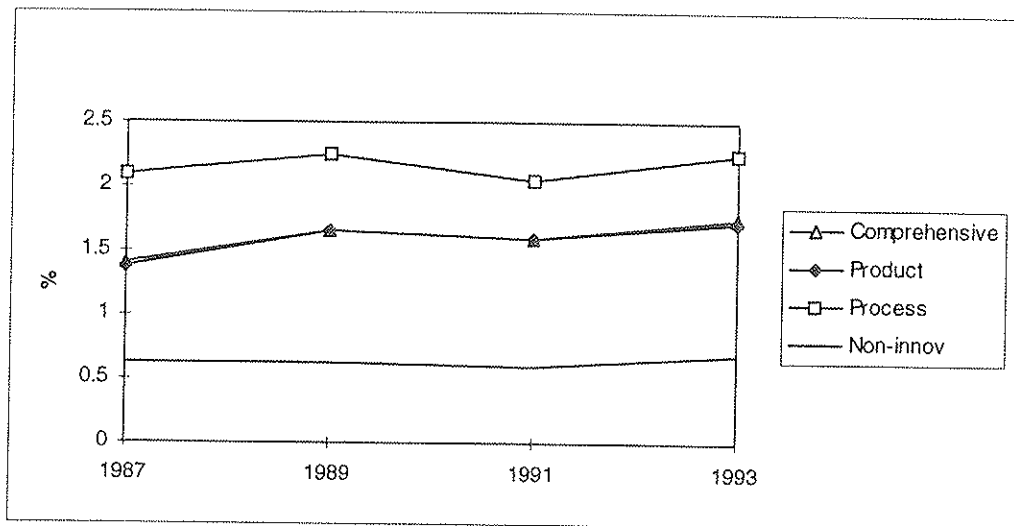


Figure 5.4 Growth of innovating firms: market share



5.3 Principal Components of Innovating Firms

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

We 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 we can account for about 2/3 of the variation in these variables.

Table 5.3 Variables

Variable	Definition
HC87	<i>Human Capital Index</i> (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

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
HIGH87	0.46	-0.03	0.12	-0.06	0.05	-0.11
HITECH87	0.46	-0.09	0.04	-0.04	0.04	-0.04
POST87	0.22	0.38	-0.09	0.10	-0.10	-0.05
TECH87	0.30	-0.17	-0.21	-0.08	-0.16	0.33
TEN87	-0.06	0.26	0.31	-0.27	0.12	0.18
ΔHC	-0.08	0.01	-0.25	0.23	0.02	0.49
ΔHIGH	-0.02	0.04	-0.40	0.18	0.49	-0.09
ΔTECH	-0.12	-0.02	0.12	0.18	0.26	-0.21
ΔPOST	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 %

Among the product innovators, the most common type of firms described by 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. The 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 competencies but work experience. In fact, the change in the share of employees with higher education is heavily negatively weighted. Instead, more employees with research competencies 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 discussed here is dominated by capital intensive firms, that have a quite wide base of technical competencies and increase more general competencies rapidly.

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
HIGH87	0.35	-0.26	-0.01	-0.07	0.24	0.09
HITECH87	0.34	-0.30	-0.03	0.00	0.19	0.02
POST87	0.36	0.31	-0.02	0.07	-0.08	-0.12
TECH87	0.20	-0.27	-0.16	0.04	-0.06	-0.23
TEN87	0.02	0.21	-0.08	-0.51	0.11	0.11
ΔHC	-0.11	0.21	0.03	0.15	0.52	-0.21
ΔHIGH	-0.02	0.09	-0.24	0.48	0.14	0.28
ΔTECH	-0.07	0.10	0.21	0.10	0.61	-0.14
ΔPOST	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 %

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-tenure 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 their low-tech counterparts. PRIN3 emphasizes again labor-intensive growth, associated with decreasing general competence level, but growth of technical competencies. 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 more or less 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.

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

6 Conclusions

In this descriptive study we have unveiled some patterns of accumulating educational competencies in manufacturing firms, and how these relate to other characteristics of the firm and industry in question. We 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 the 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 competencies, as

compared to non-innovators. In terms of economic performance, the innovators tend to be more successful, both with respect to profitability, exports and growth.

All types of innovators are also larger than non-innovating firms. Size of the firm appears to be quite an important indicator of the innovative activity it carries out. Product innovators are the smallest, quite close to them in size and other attributes too are so called comprehensive innovators, making 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. They suggest that this arises from increasing returns to process innovation due to appropriability of returns improving with size.

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. The technical and research skills are also increased with a quite fast rate. Comprehensive innovators are slightly larger than product innovators, and they also have a high level of education. Comprehensive innovators are still quite labor intensive, but the intensity has started to decrease rapidly, apparently 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 competencies, although the rate of acquiring other types of educational competencies, notably higher technical capabilities, seems to slow down.

As for the non-innovating firms, they are smaller and less successful. However, it does not seem to be the first stage of firm evolution to enter the industry with a standard product, and then start growing into a more successful firm. Instead, non-innovators perform badly throughout the period of study. 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. This supports the proposition that accumulation of competencies and knowledge through learning affect the innovative outcome and economic performance. Competencies acquired through education seem to have a significant role in this process.

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