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Research Paper no. 10/04

Materials, innovation and competitiveness in low-technology industries

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Abstract

Discussion of innovation and technological development has to a very large extent been restricted to high-technology industries. This is a serious shortcoming in the theory of innovation. In the first place, low technology plays a dominant role in the OECD economies in terms of turnover, as argued in this study. Analysis of returns on investment also suggests that this sector is more profitable than high-tech. Secondly, innovation and technological development in low-technology industries are very different from those in "high technology" and therefore cannot be analysed with the same instruments. It is characteristic of low technology that new knowledge is often transferred in embodied form. This is particularly the case with new materials, but also with other production equipment. Adapting these to the firm's own products and production processes calls for capabilities from the firm itself in the form of learning processes. These learning processes are in turn integrated with the firm's material base. Not high R&D expenditures, but low implementation costs, are thus a measure of success. The importance of different ways of obtaining access to new knowledge in low-technology industries, for example in the form of buy-ups and licensing, is also discussed.

Keywords: **low technology, innovation, materials, competitiveness**

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Materials, innovation and competitiveness in low-technology industries

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Introduction

Low-technology industries have not occupied a central position in discussions of innovation and innovation theory, despite the fact that low technology and medium technology have completely dominated the industrial structure of the OECD countries. This domination will not change in the foreseeable future; for example, more than half of those employed in the OECD are in low-tech industries [1].
This obvious neglect of low technology can be attributed either to the belief that the theory developed for so-called high-tech industries can also be applied to low-tech industries (and that there is therefore no need for an explicit theory of innovation for low-tech industries), or to the view that no innovation process takes place in low-technology industries, and these industries are therefore of minor importance in terms of innovation. We believe that both conceptions are wrong. Thus the purpose of this article is to discuss the specific conditions which surround the innovation processes in these industries and, against this background, to develop an understanding of the specific character of the innovation processes in low-technology industries and the ways in which they have taken place.

One view that has supported this focus on high technology is the opinion that the advanced economies should focus on properties and qualities of the products instead of on price competition. Instead of risking intense price competition from low-wage countries it is better to leave the low-tech product market. In this way there will be a continuous upgrading of the advanced countries. The success stories according to this theory are those countries that have been able to "exit" the low-tech field in favour of more advanced products. The classic example of this is the development of Japan [2].
In particular, the EU countries are said to be losing competitiveness to NIC and Eastern European countries in the low-tech field. An important area neglected in this discussion is the importance of competition based on properties in low-technology industries. Competition in terms of quality and design therefore also characterizes low-technology industries where the upgrading of the economy might not involve the development of high-technology products but the upgrading of low-technology products by focusing competitiveness on quality and design instead of price.

The focus on the implementation of new knowledge, specifically coded knowledge, has meant that other aspects that contribute to the competitiveness of firms have been overlooked. These factors are valid and relevant in relation to the fields of technology and innovation, but are not amongst the issues raised by the high-tech industry. A case in point is the interest shown in recent years in tacit knowledge and learning processes in relation to specific industries – an interest that has been related both to the organization of learning processes within the firm and to regional and localized learning processes [3].

As our analysis will also show, a lot of the problems of innovation raised in recent years can be placed in a historical context. They are not new, and have been part of industrial competitiveness for many years. A historically based analysis can thus shed new light on the problems and consequences associated with different development strategies. First of all, there is a relationship between technological strategies often established early in the life of a firm and an industry, and the problems faced today. Analyses of technology adaptability or shifts in strategy must therefore be done in a historical perspective. A technology trajectory is often the result of a long historical process, where earlier strategy decisions set the boundaries for future technological adaptability and strategy options.

A starting point in a historical context can therefore provide new perspectives on the technological development problems that companies face today. This historical perspective is particularly relevant and necessary in relation to low-technology firms and industries, where the development of innovation and technology has often been characterized by complex learning processes and tacit knowledge.

Low-technology industries and competitiveness.

During recent decades there have been few changes in the production structure of the OECD countries. This does not mean that there have been no changes in the products and processes of the firms, only that there have been no fundamental changes in the production structures of the OECD economies.

This rigidity of the production structure has increasingly been identified as a problem, and the issue has been accentuated with the emergence of the discussion of the relationship between technology levels and profitability.

In this discussion the popular view has been that high-tech industries will be the most expansive and profitable in the future. This argument is often based on a very few successful firms and specific industries such as the computer software and medical industries. However if we look more closely at the industrial structure as a whole, rather than simply focusing on a few success stories, we will not find this close relationship between the technology level and profitability.

A Danish study of the most successful and rapidly expanding firms in Denmark shows that there were only five high-tech or medium-high-tech firms among the ten most successful Danish firms in 1999 [4]. Five were medium-low or low-tech firms. If we look at the most rapidly expanding firms in Denmark in 1998 we will only find three high-tech firms among the top ten [5]. Another characteristic of the most successful and rapidly expanding firms was that they were all small or medium-sized. The most successful firm only had 114 employees; the next three had 170, 90 and 766 respectively. So these expanding and successful firms were also very small or medium-sized firms.

A more detailed study of the Danish industrial structure, dealing with the development of turnover and return on investment over a number of years, will give us a more accurate picture of the relationship between technology level and the expansion of production and profitability.[1]

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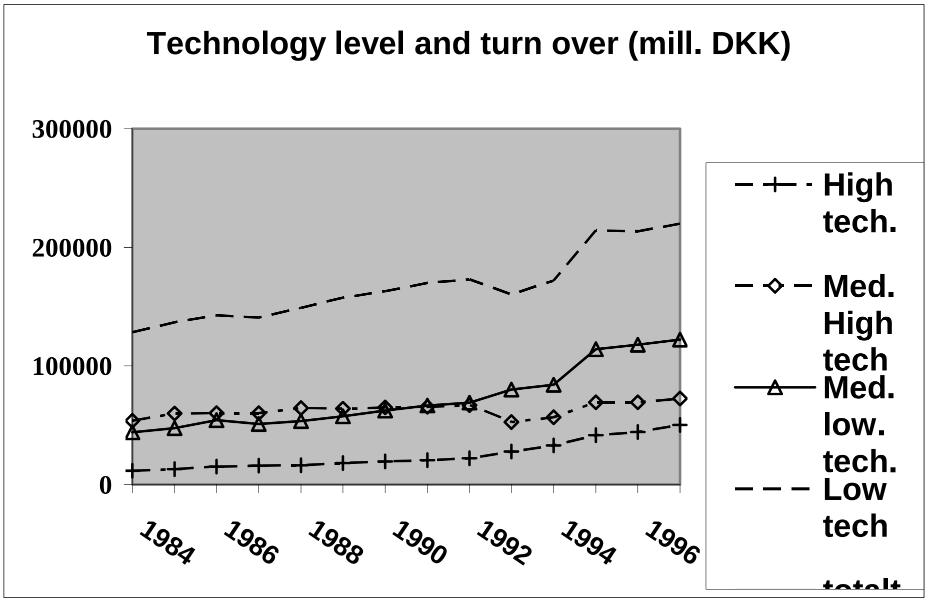
1 The division into different levels of technology is based on the one made by the OECD. In this division high-technology industries are defined as industries where the R&D content is higher than 6% of production cost, medium-high-technology industries are industries where the R&D content is between 3% and 6%, medium-low industries are industries where the R&D content is between 1% and 2%, and low-technology industries are industries where the R&D content is lower than 1%.[6] This division is based on the ISIC nomenclature. Since 1993 the EU countries have abandoned the ISIC nomenclature. The divisions in the new nomenclature are not immediately

Fig 1. Technology level and turn over 1984 - 1996

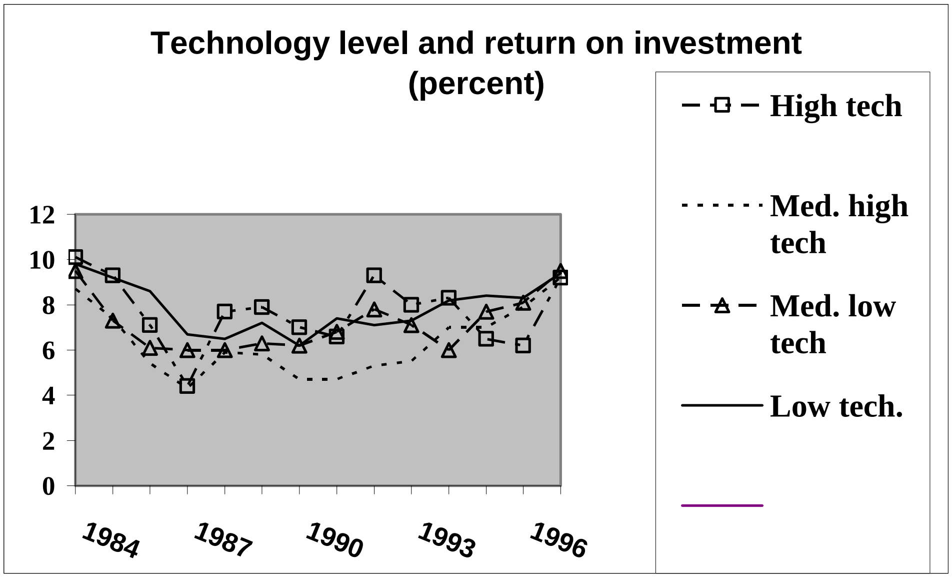


Source: Own calculations based on Denmark´s statistics.

If we look at the development in turnover in Fig. 1, what is immediately striking is the massive dominance of low and medium-low technology. Low tech's share of total industrial turnover is 47% in 1997 and medium-low-tech's is 26, while high tech's share is only 11%. Medium-high-tech's share is slightly higher. If we look at the period from 1984, no dramatic changes have occurred. High tech has increased its share from 5% in 1984 and low tech's share has decreased from 54% in 1984. These developments have, however, been counteracted by the fact that medium-high technology has decreased from 23% in 1984 while medium-low technology has increased its share from 18%. From this we can conclude that low technology still plays a very important role in the Danish industrial structure.

comparable to the ISIC divisions. The division in technology levels from 1993 onwards must therefore be based on estimates. The statistics include only those firms with 20 employees and more up to 1994. From 1995 it includes all firms.[7,8]

Fig 2 Technology level and return on investment percent 1984 – 1996



Source: Own calculations based on Denmark´s Statistics

If we look at the return on investment – that is net profit compared with total assets – we can find no support for focusing on high-technology industries. There is no clear relation between technology level and return on investment. At the start and at the end of the research period the return on investment was approximately the same, around 9-10%, for the four technology levels. However, in the last three years (1995-1997) the return on investment has been higher in low-technology industries than in high-technology industries. What also emerges from Fig. 2 is that medium-high technology generally showed the poorest result in terms of returns on investment in the period 1984-1997.

Of course this broad technology division hides the fact that there have been different patterns of development in the technology levels when one compares different industries, in terms of both turnover and return on investment. In spite of this, and since nothing indicates that conditions are very different in other countries, one conclusion of the investigation is that we can reject the popular view that there is a close relationship between high technology and profitability; and by extension, that the industrial policies supporting high- technology industries pursued today in the majority of the OECD countries have often been built up on false assumptions – a high-technology strategy does not necessarily mean increased profitability compared with a focus on low technology.

The rough analytical division in technology levels based on R&D expenditures will not give us a true picture of the way in which technological change and innovation take place. This has meant that a lot of industrial production has been defined as low technology. In reality, however, these industries are dependent on innovation and development activities in other parts of the industry. These interactions take place in the form of products exchanged over the market, between user industries and raw material and equipment suppliers – an exchange that can take place between high and low-tech industries.

Often the result of these structural relations between industries is that low-technology industries will be introduced to new technology in the form of new materials and production equipment [9]. This will take the form of relations between industries based on developments blocks in the industrial structure. [10] In this way, knowledge and innovation in other industries will be transferred by the industrial structure to firms often only termed low-tech because of their low internal R&D.

A large number of low-technology industries are also suppliers to more sophisticated end-user industries and are in this way important contributors to the final high-tech product. Plastic processing firms that produce components for the electronics industry are only one example of the relationship between different levels of the industrial structure. Another is the steel industry, where new materials such as advanced steel and composites present new possibilities for developing new products.

Some important relationships are associated with changes in the technological and material base of the firm. First, technological changes often take place through changes in the material base of the firm. This will change the basis for the firm's experience, and is therefore a difficult process. The development of the production processes of a firm is often closely associated with a specific material, and production experience related to materials is built up over a long time through the use of the same kind of material. Secondly, developments in other parts of the industry also intensify the quality requirements of low-technology industries if they are to participate in the industrial network structure. In contrast, some parts of high-tech industries use production processes and products that have not changed for a long time. The plastic processing industry and parts of the chemical industry are good examples of this relationship. So called low-technology industries thus undergo innovation and adaptability processes, and these are the ultimate conditions they must fulfil to remain competitive and stay in the market.

The role of materials and learning processes in low-technology industries.

Low-technology industries are not merely characterized by their dependence on technological developments in other parts of the industry. Just as important is the way innovation is developed and knowledge is built up through experience and learning processes in these industries. This, and the role played by embodied technology transferred over the market in the form of new materials, are the main determinants of the specific forms the innovation processes take in this part of the industrial structure. These two factors, both crucial to low-technology industry, mean that the innovation processes in these industries are not as manifest as they are in other industries, where the importance of innovation can more easily be accounted for in terms of R&D expenditures. When the innovation process takes the form of a learning process, this means that the process can take place in many parts of the firm, not only in the R&D department. The result is that the identification of the innovation process here will require a complicated analytical approach. The fact that technological change can be embodied in the form of (for example) new materials means that a large part of the innovative effort in low-technology industries consists of transforming embodied technology acquired over the market into new products and processes. Thus the fact that the innovation processes do not show up in R&D expenditures does not mean that they do not exist; only that these processes take another form, and that it therefore takes different analytical approaches to detect them.

In this relationship between embodied technology and learning processes, which is so characteristic of low-technology industries, materials play a central role for the understanding of the innovation process; first, because materials are important elements in embodied technological change. The development of new materials is almost never the result of innovation processes in the user industries. Instead they are developed in the raw materials industry and acquired over the market by the user industry, where the new materials are adapted to the user industries and their special needs.[2] This can however be complicated enough, especially in the many cases where the adaptation of the new material can take place in the production department – not unusually in trial-and-error processes. As a result, the adaptation of new materials, which is an important part of the innovation process of many low-technology industries, only shows up in the R&D statistics of the raw material industries – despite the fact that it is the result of a complex interactive process between the raw material industries and the user industries, where the experience developed in the adaptation process in the user industry is of central importance to the R&D processes in the raw materials industry.

In spite of the important role played by raw materials suppliers this indicates the specific skills that are characteristic of low-technology industries, where the ability to use and develop the properties inherent in the material in learning processes is perhaps one of the most distinguishing features of the innovation processes. This demands thorough knowledge of the material in use as well as the needs of the end users and customers.

Learning processes thus emphasize the fact that technological development and technological change are important competitive factors for low-technology industries. The ability to transfer knowledge in embodied form is a central element in the innovation processes of these industries. To be able to adopt new knowledge and technology at all, the firm thus needs to have been through the learning processes. Technology in the form of new materials and machines is the most characteristic form in which embodied knowledge is transferred in low-technology industries. This kind of technology transfer, even in the form of advanced materials, can be also handled by small firms where the "practical man" plays a central role in the organizational work.[3]

The pivotal role played by learning explains why industries in the OECD countries can successfully compete with industries from low-wage countries. The latter

2 In this process the raw material producer has often played an important role in adapting the new material to the specific user industries' needs. This is not a one-way process. Information from the user about his needs can also be of importance to the innovative activity of the raw material industry. This the market, ever since the development of the division of labour, has been supplemented by the exchange of information that the traditional market based on prices could not supply [11,12,13].

3 These are people in a firm who, through learning by doing, have accumulated experience in adapting materials and processes as well as products [14].

countries are constantly in an unfavourable position because they lack a foundation for their learning processes. Embodied technology is characteristically transferred to these countries although they do not have a pre-existent industrial environment or developed market; and this prevents the initiation of learning and development processes that can foster the further development and adaptation of products. In the OECD countries, by contrast, skills and qualities are constantly upgraded in learning processes, and this makes it possible for the low-technology industries in the these countries to keep ahead of their competitors in low-wage countries. This is often a crucial difference in conditions between low-technology industries in the OECD countries and those in low-wage countries.

Material adaptability in the plastics industry.

The plastics industry is one industry that is very dependent on material development. It is representative of industries where embodied knowledge in the form of new materials has played an important role in establishing new low-technology firms. A new material was the basis for starting a whole industry in the middle and last part of the nineteenth century. Embodied knowledge in the form of new plastics was transferred from the raw material suppliers to the plastics processors. This embodied knowledge in the form of new materials gave the processors new product and design potential. Gradually, different forms of plastic raw materials have been developed and have led to a very wide spectrum of production possibilities with an ambition to more or less "tailor" the raw materials to the property and design requirements of the product. This led to the growth of a new low-tech plastic processing industry, strongly dependent on the R&D resources of the raw material suppliers.

New materials will often come into conflict with existing experience in the processing industries. Experience is developed in the interactions among tools, materials and product design. In the plastic processing industry, skills and the knowledge are therefore related, often tacitly, to the processing of specific kinds of material. But this is only one part of the "lock-in" problems of using new materials. Another is related to the production equipment. Both represent large capital investments as well as experience resources within the firm and in its relations with its end-user.

A study of the Danish plastics industry, with some examples, can give us an understanding of dependence on materials for the development of new experience and technology in the form of new products and processes.

In the last part of the nineteenth century and at the beginning of the twentieth century, celluloid was the only material that existed in the plastics industry. Experience in the industry was built up by using celluloid for fancy goods, collars, combs, pencils and so on. Only raw film production could establish celluloid as a more "serious" product. Celluloid was central to the production of feature films and therefore to a new entertainment industry. The identification and use of the material for this purpose required totally different kinds of experience and learning processes, and, symptomatically, developed outside the plastic processing industry.

At the beginning of the twentieth century the production of a new material, bakelite, was started up. Bakelite had a different field of application from celluloid. Its primary market was industrial components, especially electrotechnical components. The difference in applicability and end-users was of great importance to the way bakelite was introduced in Denmark. In Denmark it was not celluloid processors who started manufacturing things in bakelite; it was entrepreneurs with knowledge of the application area, primarily the electrotechnical industry, who started up manufacturing based on bakelite material. The celluloid producer's experience and knowledge were restricted to celluloid and the products made out of the material, and the two material fields had no connections or shared experience.

At first bakelite was a substitute for porcelain in electric switches and other products used in the expanding electrical equipment industry. This production expanded in the thirties and on into the fifties [11,15]. In these transformation processes there was a close relationship between the electrotechnical industries and the development of the bakelite industry. Thus it was requirements in the user industry that defined the development of the new material and the related innovation processes. Consequently, the processing companies that had close relations with these industries led developments rather than the processors with backgrounds and experience in the old plastic materials.

After World War II a second material shift took place with the introduction of thermoplastics. In Denmark it was originally firms with their material base in bakelite and celluloid that started production in the new material. These pioneer firms were not successful. Instead, it was people with no experience of industrial practice who started and built up the plastics industry in Denmark; for example people who started up production in chicken sheds, garages and old farms. The point of departure for these 'unskilled' entrepreneurs was that they were able to see the possibilities of the new material because they were not constrained by the experience of the old plastics industry.[4] They had no connections with traditional users and were therefore able to build up relations with new groups of users.

At first they produced a lot of different products. As was the case with celluloid, these were primarily fancy goods, but also buckets, toys etc. An important reason for this product mix was that these products did not have a low tolerance threshold like the technical products. So there were rich opportunities for trial-and-error and as a consequence this was a good place for developing experience and learning about the new processes and materials. And indeed to begin with they made a lot of mistakes.

Slowly, as the new material developed and experience in the use of tools and machinery was gained, specialization took place. This specialization changed the core qualification in the plastics industry from plastic processing – that is, injection moulding in general – to the processing of different products made from plastics. This was a very important change in the development of the industry. This specialization took place in the plastics industry in the sixties. It was no longer the material, plastic itself, that was the focus of the experience, but the product and the specific kind of plastic it required to ensure its specific properties. This development took place in an interaction among processors, toolmakers and the

4 Few firms from the old plastics industry were able to change to thermoplastics - primarily firms that had changed from having the material as their base for production to having the product as the firm's identity.

raw materials industries on the one hand and end-users on the other. One important barrier for this specialization has been the ability to guarantee a sufficiently large production volume to make the development of specialist knowledge profitable. The specialization process thus took a long time and has not proceeded at the same pace in every part of the plastics industry. Today the plastics industry is therefore divided into a lot of different product groups, each with its own specialized knowledge and learning processes.

The problem of changing the material base in low-technology industries can be illustrated by some examples from the building industries. One example is the shift from the traditional materials, concrete and metal, to plastics for the production of sewage pipes. Manufacturers of concrete articles only produced sewage pipes as one of a range of products associated with concrete. Their expertise was closely connected with this specific material. In all cases it was impossible for them to change their material base to plastics. Their industrial experience was too far from the new material and its adaptability requirements. New plastics processors took over the production of sewage pipes; at first as one product among others in plastics processing, but even in this case, the specialization changed the structure of the manufacturing process into a new specialization. Important elements in this development were the relationship between users (processors) and the raw material supplier on the one hand and the relationship between users and processors on the other. In this way the processor was in a position in between the material supplier and the end-user, able to make use of both the former's knowledge of materials and the latter's experience of user needs. These developments and specialization processes took two decades [16]. The process often started with the establishment of a specific department within the firm. Later a specific firm was set up or the specific part of the firm was sold.

Material adaptability in the metal packaging industry.

In the metal packaging industry, too, materials played and still play an important role in the development processes. Characteristic of both the metal packaging industry and the plastics processing industry are their close relations with both supplier and end-user industries. Development in the metal packaging industry has taken place in close association with the food industry; indeed the industrialization of the food sector depended on the development of functional forms of packaging. It would therefore be easy to reduce the emergence of metal packaging to a simple demand-pull process. This impression is strengthened by the fact that the first, dominant metal packaging, that is cans, were produced at the canneries [17,18]. In the beginning it was primarily the army, the navy and scientific expeditions that were the customers for the new product. The emergence of metal packaging was also a consequence of deeper structural changes such as urbanization and the development of wage labour [19].

The supplier industry, in this cases the iron and steel industry, was also a prerequisite for the establishment of a metal packaging industry. A necessary condition for the development of metal packaging was the development of a material which was at the same time strong and easy to process and form. This was first accomplished with the development of the hot roll method in 1730 and of the Bessemer method in 1855-56 [20,21]. Thus the metal packaging industry was dependent on embodied technology in the form of the development of more and more sophisticated materials from the iron and steel industry. In these circumstances it can be argued that there was a strong element of "science push" in the establishment of the metal packaging industry.

In fact, much of the material development in this industry was the result of close collaboration between the two industries. The packaging of the individual product required the development of a specific, suitable material. Thus one can say that the "tailoring" of products has been characteristic of the relationship between the metal packaging industry and the iron and steel industry for almost a century [22]. One consequence of this has been that large, essential parts of the innovation process in metal packaging have taken place in the raw materials industry, even though demand and adaptation processes in the metal packaging industry itself have been of great importance to the specific innovative development of new materials. In this sense one can say that the technological level of the metal packaging industry has only been expressed by the R&D level of the iron and steel industry. This is because large parts of the innovation process have only been registered as innovation in the raw material industry, not in the metal packaging industry as such. The technological level of the metal packaging industry has thus been systematically underrated because neither its own contribution to the research nor the embodied technology has been registered.

This dependence on the raw materials industry has also meant a loss of flexibility in the metal packaging industry, since the learning processes have been restricted to the specific raw material industry. As mentioned previously, the learning process is closely tied to the processing of specific materials. These learning processes are a source of both opportunities for and barriers to the development of the industry. The opportunities can be exploited to the full as long as the firm sticks to a material. However, if a firm changes its material base, the exploitation of the properties of the new material requires new and different learning processes. The adaptability process of the metal packaging industry was therefore constrained by its material base. This inflexibility was in turn constrained by the fact that many of the learning processes took place in the raw material industry and were transferred as embodied knowledge or technology to the industry. As a consequence, new materials and new products based on these materials were introduced by new firms, not the old established firms in the packaging industry in Denmark.

The importance of materials is also expressed in the way the metal packaging industry was established. In the beginning, the production of cans was part of the canning industry. It was the users who produced their own cans. One reason for this was that cans were not regarded simply as packaging but as an integrated part of a new preservation process – that is, canning – and were therefore a natural part of the food industry's knowledge base. Another reason was the low volume at the start, when canning was just a niche product. When the volume rose and new canneries were established, there was a basis for specialization and the development of the division of labour. This was a process that took place particularly in the last part of the nineteenth century, when a separate can-producing industry grew up in both Denmark and the rest of the western world.

In this way a specialized knowledge base was created, which could speed up the technological development. Although some of these new firms had their origin in the canning industry, it was firms with a basis in tin production that survived. This again points to the importance of the material base as a prerequisite for learning and for product development. Although the material base was one condition, it was not enough. Another characteristic of the development was specialization. The firms that became dominant on the market were not just tin ware factories, but specialized producers of cans. As with the plastics industry as it developed, material knowledge alone was insufficient. More central to the learning process were the relationships among the product, the properties required and the material.

Materials as a basis for innovation strategy in the Danish metal packaging industry.

We will use some examples from the Danish metal packaging industry to bring out the importance of different strategies for innovation and technological development in low-technology industries. In the Danish metal packaging industry we can identify both an innovation strategy and a strategy based on licensing.

In the case of the Danish tube industry, an innovation strategy was founded on specialization and knowledge of specific materials. The firm Andersen & Bruun built up an international business with a strategy based on incremental innovation in relation to specific materials, in this case tin and lead. These materials had special problems – tin was expensive and lead was toxic. Andersen & Bruun tried to solve these problems with different design solutions and by introducing new machines. The concept was to build up a complete technology system based on licensing, where Andersen & Bruun supplied the machines together with the new products. It was a strategy based on the company's own innovations. The firm established licensing production in 32 countries, and owned firms in Denmark and England.

The problem with this strategy was, however, that when aluminium was introduced the problem was solved once and for all, and the basis for the incremental innovation strategy disappeared, thus reducing the firm from a world-wide concern to a strictly Danish company. The new material, aluminium, changed the material base of the firm. Ironically, aluminium was a starting point for a new material base, not for the production of tubes but for other packaging products such as bottle cases and packaging for chocolates. In this product field it was possible for the firm to make new innovations from the new material base. However, the era of innovation in tube production was over. The focus mainly turned on the Danish market and on the economization of production processes, as in much of the metal packaging industry. New tube manufacturers, with experience of other product fields, took over production. They had a new vision of production, namely economization.

Licensing and innovation strategy.

Licensing has played an important role in the development of the metal packaging industry; not only in the diffusion of new technologies and innovation, but also for the innovation process itself. However, relatively little interest has been shown in the importance of licensing in the innovation and learning process. Most of the interest has focused on the legal side of the matter – that is, how to construct licensing contracts that give the greatest protection to the innovator and licensor and ensured returns for the innovator [23, 24]. Of course, the appropriation of the benefits of innovation is not a matter of minor importance for the innovation process.

Indeed, the vast resources generated from licensing overseas were of tremendous importance for the "Big Two" in the USA, American Can and Continental Can. Both had licensing as a crucial part of their competitive strategy. Their international licensing strategy was really an extension of their home market competition strategy. This meant that they supported competitors in the different national markets where they were licensed. In the case of Denmark, for instance, they supported the two big rival firms: American Can licensed to Glud and Marstrand and Continental Can licensed to Haustrup. The importance of licensing is also shown by the fact that the different licensees of American Can joined forces in a "European Can Association". In this way they achieved a critical volume which enabled the large American firms to continue their development strategy based on innovation. The important role of licensing is also documented by the fact that it was the very successful licensing strategy in Europe of Continental Can that allowed the company to take over the role as the dominant producer and innovator of metal cans from American Can in the late forties and at the beginning of the fifties. Before this American Can had been the undisputed innovative leader [25, 26].

The importance of licensing as a strategy in metal packaging in Denmark is supported by the growth of the tube producers Andersen and Bruun from a national to a global firm. This national expansion was founded on a succession of incremental innovations in both products and machines, which were licensed together as a complete technological system [27]. These vast licensing activities enabled the firm to establish its own R&D department and hence to continue its incremental innovations for many decades.

According to the huge amount of literature on licensing, there can be many reasons for this strategy [28, 29, 30]. A widespread theory of licensing is the stage theory – that is, the theory that firms license when they are young and small and therefore do not have the resources to enter new foreign markets. Another type of stage theory argues that firms license at the end of a product cycle to squeeze the remaining profits out of the old technology [28]. As we have seen, in the metal packaging industry neither of these was the case. Here it was two very large firms which saw licensing as a major instrument for developing their innovation processes and therefore practiced this policy while developing the new technology.

In the case of the metal packaging industry the role played by licensing is basically conditioned by the characteristics of the products of the industry. The most characteristic feature of the metal packaging products is their low value in relation to volume.[5] This makes it impossible to transport the product over even relatively short distances. For example, the profitable export of tubes from the Copenhagen

5 This conspicuous characteristic, however, has far-reaching consequences, and for instance means that there are severe limitations in the theory of comparative advantages - that is, the theory that countries should concentrate on the production of products where access to factors of production is easy and therefore relatively cheap, and should import products where access to production factors is limited and therefore relatively expensive. In other words advanced countries like the OECD countries should focus on high-technology products, and low-wage countries should concentrate on low-technology products. This disproportion between volume and value is one explanation of the existence of low-technology products like metal packaging in the OECD countries [14].

region is restricted to northern Germany and southern Finland. This basic fact excluded exporting as a strategy in the metal packaging industry.

From a learning perspective, licensing can be seen as a convenient and easy way to transfer and access new knowledge. Through licensing, whole technological systems in the form of complete production systems and developed products can be transferred. However, effective licensing requires that the licensee has developed resources in the form of skilled workers, a developed marketing function that provides access to the market, a smoothly functioning organization, and capital. Often licensing will only be a part of a firm's product mix or may simply be a new way of producing a product which has already been developed. This type of licensing has for example played an important role in the adaptation process of the Danish metal packaging industry. Therefore, if the licensed technology is to be used effectively, this new technology must be rooted in the firm's own experience, which is only possible if the firm has already undergone learning processes in the field. Thus the firm will be sufficiently mature to take up the new technology. This was the case for the Danish firms Glud and Marstrand, and Haustrup, which had already been producing cans for decades before entering into a licensing agreement with the American firms.

Licensing can also be regarded as the most extreme form of the embodiment of knowledge, in the sense that the transfer of knowledge inherent in the technology is formally and legally regulated. These legal regulations are there to protect the licensor and thus to restrict the learning processes of the licensee, even if the latter often tries to circumvent this. This means that the licensee often becomes completely dependent on the licensor's R&D activities instead of developing and adapting its own technology. In this way licensing means, that the firm obtains easy access to new technology at the price of impeding its own technological development and flexibility.

Conclusion

In spite of more than 20 years of focus on the importance of high-tech industries in academic and political discussions, low-tech industries still have a dominant position in the production structure of the OECD countries. This is expressed both in terms of employment and in our investigation of turnover at different technology levels in Danish industry. Our study of returns on investment also shows that development over the last few years has been better in low-tech industries than in high-tech ones. These very elementary facts have been totally overlooked in contemporary innovation analyses and in technology policy. The importance of low-tech firms in the OECD countries makes it evident that there are important elements of innovation and technological change in low-tech industries that cannot be analysed with the traditional instruments developed to appraise technology development and competitiveness in high-tech industries.

First of all, material and learning processes play an important role in low-tech industries. The traditional way of measuring the technological level in terms of R&D expenditures makes no sense in relation to low-tech industries. In low-tech industries new technology is often adopted and implemented in the embodied form of new materials and new equipment, and in the form of licensing. These forms of technological development do not create R&D expenditures in the firm. Instead they draw on the firms' own abilities to use learning processes to adapt new materials or new technology to the firm's product and market conditions. Not high R&D expenditures, but low implementation costs, are therefore a measure of success.

By analysing examples from the plastics and metal packaging industries we can see that changes in materials, learning processes and licensing have played a central role in the technological development of these low-tech industries. The learning processes are based on experience of specific materials. Our study shows that it was not possible for firms already established in a particular material trajectory, with their point of departure in their own knowledge base, to adapt to new materials. Instead, they have had to buy up other firms, or a new industry has grown up, establishing its own learning processes and experience, where the point of departure for the new firms has been that they were "unskilled" in the sense that they lacked both experience of the new material and industrial experience in general. This kind of accumulation of experience is, however, only possible at the beginning, when the material is new. Less complicated products functioned in this phase as a training field for gaining experience for the development of the industry.

One way to solve the problem of the dependence on a material trajectory has been to buy up new firms which already have experience of using new materials. In this way new material experience was transferred to the firm. This strategy has often been used when a new material has been introduced in a new product field. Another method has been licensing. This strategy has been used when the firm's production volume was not large enough to guarantee a profit that made it possible for the firm to rely on its own R&D. The advantage of licensing is the easy transfer of knowledge, while the disadvantage is a loss of flexibility. The firm is now not only dependent on a material trajectory, but also on the licensor, since it lacks its own R&D capacity to meet – for example – threats from new materials.

Innovation and technology development in low-tech industries require adaptability skills, the market knowledge that comes from closeness to the market, and learning processes and experience related to the material and technology used in the firm. New technology, and particularly new materials, play an important role in low-tech industries. This is one of the most important explanations of why low-tech industries still play an important role in most of the high-cost countries in the OECD area.

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