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Hansen, Teis

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

The Danish fabricated metal industry: A competitive medium-low-tech industry in a high-wage country

Teis Hansen

Department of Human Geography, Lund University

Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University

This paper aims to contribute to the knowledge on innovation processes in low- and medium-low-tech industries. Today, industries characterised as high-tech are perceived to be central to economic development, as the research intensity shields them from competition from low-wage countries. This is less the case for low-tech industries, but their economic importance continues to be large, however. It is thus interesting to analyse how they manage to remain competitive.

The analysis focuses on a case study of the fabricated metal industry by identifying the innovation strategies followed by firms located in a part of Jutland, where this industry has experienced growth. It is found that the ability to create tailor-made solutions is central to the competitiveness of these medium-low-tech firms. Knowledge is thus highly important, yet in different ways than for high-tech industries. This illustrates the importance of industrial policies that take these differences into account.

Keywords:

Innovation, low-tech, industrial development, Denmark, fabricated metal industry

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Introduction

Spatial development strategies in industrialised countries increasingly emphasise the crucial character of production and diffusion of knowledge for the innovativeness of firms (Garofoli, 2002). Continuous innovations are seen as necessary to remain competitive in the present knowledge economy (Maskell & Malmberg, 1999). In most instances, attention focuses on a number of high-tech industries which are perceived as central to economic development. In the current financial crisis, high-tech industries are often considered as vital to economic recovery (Pisano & Shih, 2009), and the relationship between these industries and national competitiveness is the centre of much research (e.g. Newman et al., 2005). Consequently, more and more regions choose to focus on industries such as IT, biotech and nanotech. Attracting and supporting firms within these areas are viewed as strategies which are sensible in the long run, but it is also recognised by scholars that many regions simply do not have the characteristics needed to support economic development within these fields (Malecki, 2004). Still, policymakers give less attention to industries which are not as directly related to scientific research (Jacobson & Heanue, 2005). These industries are seen as more prone to competition from low-wage countries, even though their economic importance continues to be large and constant in most industrialised economies, including Denmark. Yet, the Danish government's industrial policy stresses the crucial importance of research and development (R&D) for economic development (The Danish Government, 2006). As a result, policymakers take relatively little notice of the needs of a large share of the economy.

The main aim of the paper is to contribute to the understanding of the ways innovation happens in these industries, which are often given less attention than their size justifies. The paper presents a case study of fabricated metal firms in the northern part of Jutland, Denmark. Analysing how low-tech industries manage to remain competitive in high-wage countries through different forms of innovation processes is of key importance for policymakers' abilities to provide the optimal framework conditions for such firms. Thus, the research question of the paper is:

How do Danish low-tech and medium-low-tech (LMT) industries innovate and remain competitive despite the wage disadvantage relative to other countries?

Such knowledge makes it possible to structure the Danish business support system around the needs of low-tech firms and ensure that the educational system provides the students with the skills required. The paper finds that both issues are matters of concern today.

The paper is divided into five further sections. The subsequent section provides a theoretical basis for the analysis. It focuses on theories about innovation processes in industries which are not characterised as high-tech. The second section gives a brief overview of the economic importance of Danish LMT industries followed by a section characterising the fabricated metal industry. The case study is analysed in the fourth section, which constitutes the main part of the paper, while the final section presents a discussion of the results of the analysis, specifically in relation to government policy.

Innovation in LMT industries

The innovativeness of firms is crucial for economic development – especially in the present knowledge economy (Maskell & Malmberg, 1999). Knowledge on innovation processes is therefore of significant importance, but most studies focus on high-tech industries such as biotech (e.g. Liebeskind et al., 1996; Audretsch & Feldman, 2003; Cooke, 2004; Coenen et al., 2004; Moodysson & Jonsson, 2007), while LMT innovation processes are less well-described (Hirsch-Kreinsen, 2005).

Innovation in LMT industries rarely happens as a result of firms' investments in scientific research. This does not imply that these industries are less innovative, but rather that innovation happens in different ways. Innovation in LMT industries is primarily based on a synthetic knowledge base that utilises existing knowledge rather than creates completely new knowledge, while high-tech industries are characterised by an analytical knowledge base emphasising knowledge creation through the use of scientific methods and modelling (Asheim & Gertler, 2005; Asheim & Coenen, 2006). Naturally, many firms combine the two ideal types of knowledge bases, and Jensen et al. (2007) actually find that such firms tend to be more innovative than firms relying on only one of the two knowledge bases. This contribution shows how the Science, Technology and Innovation (STI) mode (associated with the analytical knowledge base) and the Doing, Using and Interacting (DUI) mode (associated with the synthetic knowledge base) complement each other: experiences and practical knowledge are most often essential for scientists working in R&D departments of high-tech firms when designing research projects and interpreting results, and in the same way, scientific knowledge can often be part of the solution for firms which otherwise emphasise learning-by-doing and learning-by-using. Accordingly, the STI and DUI modes are not completely dependent on the analytical and synthetic knowledge base, respectively, but include elements from both (Asheim, 2009).

In accordance with Jensen et al. (2007), Lorenz & Valeyre (2006) observe a clear correlation between a high rate of technological innovation and an organisational form promoting high individual responsibility and common problem solving, which is typical of the DUI mode. Promoting interactive

learning at the workplace is therefore of significant importance for all types of firms (Arundel et al., 2007), but it is of particular importance for LMT industries, which primarily depend on a synthetic knowledge base. This is, to a high degree, founded on the transformative and configurational capabilities of the workforce (Bender & Laestadius, 2005).

Transformative capabilities allow firms to convert global knowledge, which is available worldwide, to knowledge which is specific to a certain context. Such local knowledge is always tacit to some extent, while global knowledge is codified. The transformative capability is thus to combine the general knowledge with practical knowledge about the specific locality. This does not result in completely new products or processes, but rather in local versions of products or processes that are generally known. Innovation thus results from the ability to create such local solutions (ibid., 2005).

Configurational capabilities make it possible for firms to synthesise novelties by organising knowledge, artefacts and actors in new ways. The authors point out three different aspects of these capabilities. Firstly, such capabilities arise from the capacity to combine knowledge from different areas in new ways. The exact combination of knowledge – codified or tacit, scientific or practical, held by individuals or teams – may vary, but the timing and speed of this creativity are crucial. The ability to create or predict future demands is of great value to firms. Secondly, combining different types of knowledge often involves cooperation with external actors. The ability to organise such cooperations, which makes the necessary knowledge available, is therefore also essential. This is especially the case for smaller companies which often do not have the resources to hire the necessary staff, and active participation in the local economy is therefore correlated with innovation capacity for LMT firms (Petrou & Daskalopoulou, 2009). Thus, up-to-date knowledge about potential partners is important for these firms. The third aspect concerns the design of specific solutions which can be described as the ability to convert this combined knowledge into products or processes that fulfil specific needs. That this ability has been important for firms in general has been overlooked (Walsh, 1996), but it is imperative for LMT firms (Santamaría et al., 2009).

However, this distinction between transformative and configurational capabilities is fundamentally analytical, and it is empirically difficult to separate the two dimensions (Hirsch-Kreinsen et al., 2006). Nevertheless, it is very useful to be aware of the different capabilities which are important for the innovative abilities of LMT firms, as these underpin the different innovation strategies available to the firms (Hirsch-Kreinsen, 2008).

LMT innovation strategies

The first of these innovation strategies is termed *step-by-step*. It is based on a continuous improvement of the product produced, and the general attributes of the product thus evolve slowly. This strategy is especially followed by firms producing goods with relatively low fluctuations in demand. Capabilities that allow firms to take up and transform knowledge already available in the specific context are central to this strategy.

A second innovation strategy is *orientated towards the customers*. This strategy is primarily based on the configurational capabilities. Combining existing knowledge in new ways creates new products or production processes, and customers often act as innovation stimulators as well as testers of new products (Fagerberg, 1995). Moreover, in some instances, customers can also act as technology agents by providing LMT firms with knowledge on the products and technologies used by competitors (Chen, 2009). Firms in many different industries use the customer-oriented strategy, and it is generally becoming more important for firms to be aware of the market demands, especially of key customers (Hansen & Serin, 1997; Mendonça, 2009).

Finally, Hirsch-Kreinsen (2008) describes *process specialisations*. This innovation strategy is mostly carried out in firms which are producing goods involving a relatively high degree of automation, e.g. the food processing industry. In this case, innovation depends on capabilities which make it possible to combine new knowledge with the practical knowledge specific to the individual firm and production process. Especially this innovation strategy involves the participation of all employees in the innovation process. Firms pursuing this strategy therefore employ people who have traditional

technical skills as well as competencies related to new technologies. Heidenreich (2009) confirms the importance of this type of innovation for the development of LMT firms, as 36 % reports process innovations over a three year period (CIS4, 2002-2004) compared to 17 % of high- and medium-high-tech firms. Furthermore, Kirner et al. (2009) finds that the quality of products made by low-tech firms is superior, which indicates that these firms give more attention to the fine-tuning of production processes than firms with high R&D intensity.

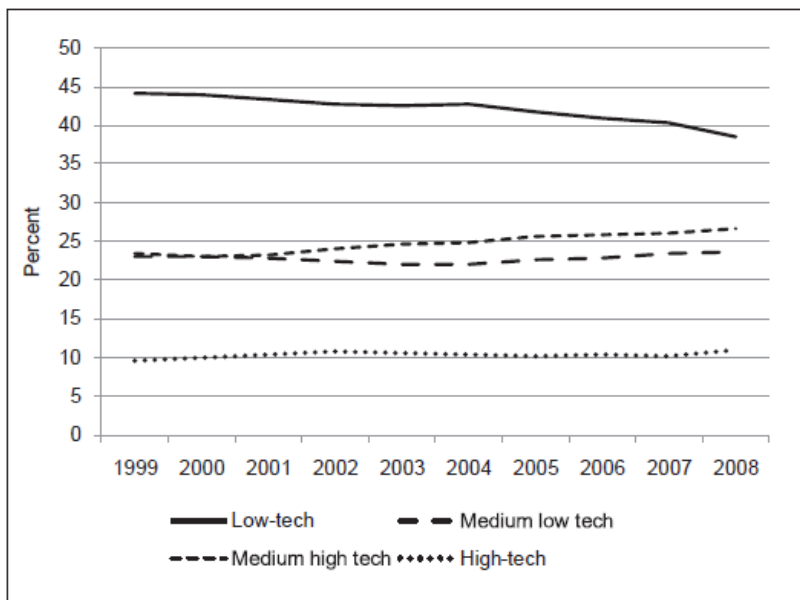
To sum up, there is a great difference between the ways knowledge is used in the innovation processes in the LMT sector compared to the high-tech sector. This is due to the fact that high-tech innovations are much more focused on the actual role of technology. LMT firms are using technology, while high-tech firms are selling technology (von Tunzelmann & Acha, 2005). However, even though this is the general picture, it is not always the case. Mendonça (2009) as well as Robertson & Patel (2005) show how firms from LMT industries increasingly patent their products within high-tech areas. LMT firms are thus integrating and diversifying into e.g. biotech, information and communication technology (ICT) and new materials. Subsequently, high-tech knowledge is increasingly becoming important for innovation in LMT industries.

Danish LMT industries

One of the Danish government's goals is to promote Denmark as a leading knowledge-society (The Danish Government, 2007). This is also very evident in the government's Globalisation Strategy where the two main foci are education and innovation (The Danish Government, 2006). Even though issues related to user driven innovation are considered in the strategy, most attention is given to the importance of R&D for the innovative capacity of firms.

Still, figures from the OECD's STAN database show that the low-tech sector continues to constitute approximately 35 % of Danish exports (2006). Furthermore, figure 1 shows the shares of employment in total manufacturing according to R&D intensity, and it is seen that low-tech industries are also hugely important in these terms.

Figure 1: Shares of employment in total Danish manufacturing, 1999-2008



Source: Own elaboration on the basis of figures from Statistics Denmark (RAS9).

The figure shows that the shares have actually changed over the last ten years; however, the change cannot be characterised as dramatic in any way. The employment in the low-tech sector continues to

be by far the greatest, even though it has decreased approximately 6 % over the period. Moreover, the share of low-tech employment is still substantially larger in Denmark than in a sample of eleven OECD countries (Kaloudis et al., 2005). The Danish 1999 share of low-tech employment at 44 % is approximately 10 % larger than the equivalent 1999 share in the eleven OECD countries. The decrease in the share of Danish low-tech employment to around 38 % in 2007 should therefore be seen as a development towards the OECD average, which was at 35 % at the end of the data series (1999) presented by Kaloudis et al. (2005).

These figures illustrate the continuing importance of industries with low R&D intensity for Danish economy. One of these industries is fabricated metal, which is the third most important Danish industry in terms of employment with a workforce of more than 42,000 (2008), equivalent to 10.4 % of manufacturing employment. The following section depicts the development of this industry over the period 1993-2006.

The Danish fabricated metal industry

The fabricated metal industry encompasses the production of pure metal products without moving parts such as tanks, steam kettles, cutlery, hand tools, fittings, bolts, nails and cans. Furthermore, it also includes such metal processing as moulding, welding and coating (Statistics Denmark, 2002). It is interesting to note that very little has been written about the Danish fabricated metal industry despite its large economic importance. Only few of the niches within the industry have been analysed:

- Christensen & Munksgaard (2001) analyse the stainless steel cluster in the Triangle Region, which is characterised by dense input-output relations. There are many SMEs within the area, but they are seldom involved in innovative projects by the few important end-producers that dominate the inter-firm relationships.
- The work by Hansen & Serin is focusing on metal packaging. This niche has been characterised by specialisation and acquisitions since its establishment in the 1920s, and the development has been more closely connected to the success of the Danish food manufacturing industry rather than to the innovative capabilities of the firms (Hansen & Serin, 1999; 2000).

Besides these contributions, the development of the fabricated metal industry has so far been of little interest to Danish scholars. One aspect is, however, clear: outsourcing is a significant process in the industry. 30 % of all Danish iron and metal firms outsourced to low-wage countries from 2001 to 2004 (Hansen & Mortensen, 2006). The reason for this is the intensifying international competition, which makes it necessary to outsource the labour intensive parts of production processes to low-wage East-Asian countries. This led to a decrease in the number of especially smaller metal firms during the 1990s (Danish Business Promotion Office, 2001). The manufacturing of complicated metal goods and/or batches of limited size has, however, been kept in Denmark to a large extent (Jørgensen & Banff, 2004).

The industry's skill level has been characterised by a decline in the share of employees with primary education, which, to a large extent, corresponds to the increase in personnel with vocational education (table 1). The share of employees with vocational education is the second largest of all Danish industries, only surpassed by manufacturing of other transport equipment.

Table 1: Highest education level attained by employees in the fabricated metal industry.

	1993	1996	2002	2004	2006
Primary school	39.4%	38.1%	32.8%	31.5%	31.0%
Ordinary secondary school	1.6%	1.8%	1.9%	1.8%	1.7%
Technical secondary school	1.2%	1.3%	1.4%	1.3%	1.5%
Vocational education	47.5%	48.0%	52.2%	53.0%	53.2%
Short further education	3.2%	3.4%	4.4%	4.8%	4.9%
Medium-long further education	3.5%	3.8%	4.1%	4.2%	4.3%
Bachelor degree	0.2%	0.3%	0.3%	0.4%	0.4%
Long further education	0.5%	0.7%	0.8%	0.9%	1.0%
Scientist	0.0%	0.0%	0.0%	0.0%	0.0%
Unknown	2.8%	2.5%	2.1%	2.0%	2.0%

Source: Own elaboration on the basis of figures from Statistics Denmark (RAS9).

Table 2 shows that the employment of the industry has been moderately declining since 1996, particularly in the urban municipalities (containing a city with more than 40,000 inhabitants), where the decline accelerated at the end of the period. The rural municipalities (all towns have less than 10,000 inhabitants) have, on the other hand, maintained a relatively constant employment. The relocation process of the fabricated metal industry, which took place in the 1970s and 1980s from the greater Copenhagen area to especially the peripheral parts of Jutland (Winther, 1996; Kristensen, 1999), thus seems to be continuing, however at a slower pace.

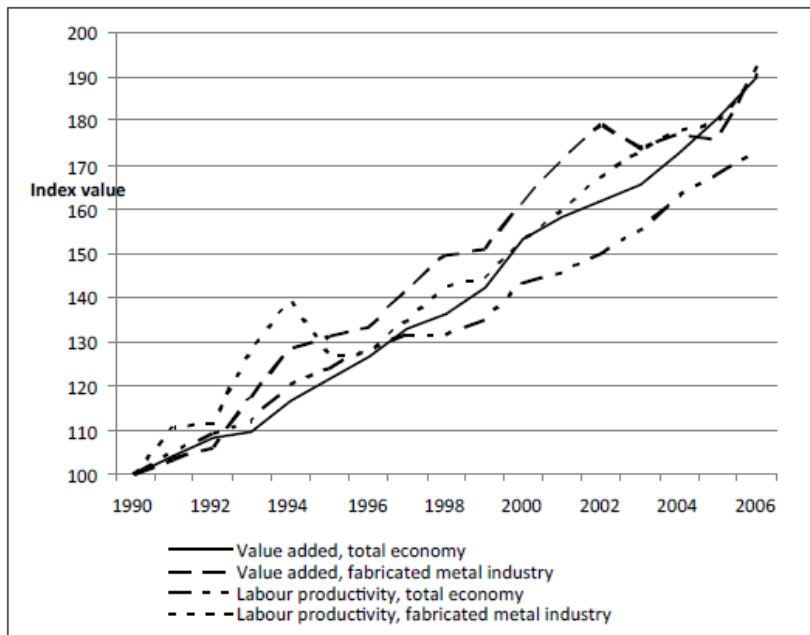
Table 2: Fabricated metal employment according to municipality characteristics.

	1993	1996	2002	2004	2006	Δ 1993-2002 in %/year	Δ 2002-2006 in %/year
Urban	17,119	16,724	15,616	14,437	14,118	-1.0	-2.4
Intermediate	11,764	12,134	10,733	10,571	9,939	-1.0	-1.8
Rural	17,853	18,981	19,172	18,122	18,670	0.8	-0.7
Total	46,736	47,839	45,521	43,130	42,727	-0.3	-1.5

Source: Statistics Denmark (RAS-database).

Still, the fabricated metal industry continues to remain competitive. The development from 1990 to 2006 of the industry's value added and labour productivity (defined as value added per working hour) is compared to the similar development of the total Danish economy in figure 2. In terms of value added, the increase of the fabricated metal industry was above the total economy's increase throughout the 1990s, but the index values were similar during the last two years of the period. With respect to labour productivity, it is interesting to see that the index values of the fabricated metal industry have been constantly higher than the corresponding values of the total economy. These findings confirm that the industry develops in a way which is at least as positive as the development of the Danish economy as a whole.

Figure 2: Development of value added and labour productivity (current prices), 1990 = index 100.



Source: Own elaboration on the basis of figures from Statistics Denmark (NATE1301 and NATE1304).

One of the regions where the fabricated metal industry has been performing well in the period 1993-2006 is an area in the northern part of Jutland from Brønderslev and Dronninglund in the north to Bjerringbro in the south. The municipalities which make up this area are characterised by a high concentration of fabricated metal employment relative to the rest of Denmark, and furthermore, they have increased this concentration over the analysed period. Finally, the municipalities have also performed better than the fabricated metal industries in a European peer group consisting of Finland, France, Germany, Sweden and the United Kingdom, which indicates that the international competitiveness of the area is also improving. A detailed description of the methodology and results of this quantitative analysis can be found in Hansen (2009), but it will not be included here, as this paper focuses on the qualitative analysis of the innovation strategies utilised by firms in this area. The subsequent section will thus seek to clarify the innovation strategies which lie behind the positive development of the area's fabricated metal industry. The analysis is based on 20 interviews with key actors from firms, educational institutions and industrial organisations. The firms are

selected so that small and medium-sized enterprises (SMEs) as well as large firms are included in the analysis in addition to both firms focusing on exports and domestic markets.

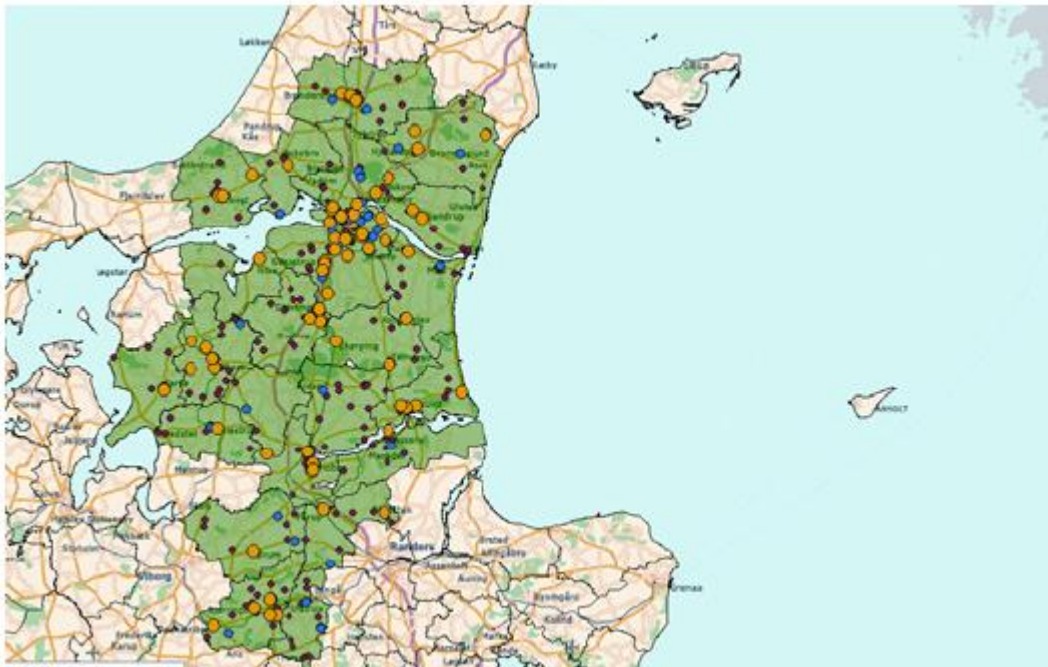
Innovation strategies in the fabricated metal industry

The case study area consists of 15 municipalities (according to the 2006 administrative structure) shown in figure 3. The importance of overall industrial activity for employment is very different among the municipalities – the share of industrial employment varies between 6 % and 30 %. Thus the area cannot be described as a traditional industrial district like e.g. the Herning-Ringkøbing area, where a concentration of fabricated metal firms is also found (Hansen, 2009).

The dots on the map show how the 414 fabricated metal firms are spread out over the area. 160 of the firms have five or more employees, while 82 firms have at least 20 employees. Concentrations are found around the cities of Aalborg, Hobro, Hadsund, Brønderslev and Bjerringbro.

Figure 3: The case study area.

Small dots: < 5 employees – **Medium dots:** 5-19 employees – **Large dots:** > 20 employees



Source: Own elaboration on the basis of data from Experian. Map copyrights: Kort & Matrikelstyrelsen.

Innovation strategies

The interviews very clearly confirm the great importance of transformative and configurational capabilities for the innovation processes in the case study area's fabricated metal firms. The majority of the firms primarily rely on a synthetic knowledge base, and the three different innovation strategies described by Hirsch-Kreinsen (2008) are widely used and combined by the firms.

The *step-by-step* strategy is the least prominent innovation strategy among the three, even though it is still of major importance for some of the firms. One example is a firm producing metal products which meets the high surface-quality requirements of e.g. some of the most renowned Danish furniture firms. Surface technology is a field where very few radical innovations take place today, but the firm continuously improves the surface quality of the products in order to maintain its position as a preferred sub-supplier to high quality furniture producers. A second example is a producer of combustion plants mainly used for bio fuel. The fundamental technology is also well-known within this subject, and the firm's competitiveness thus mainly depends on the ability to reduce the plants' emissions. Therefore, innovations for this firm are closely related to a continuous improvement of the product.

The strategy *oriented towards the customers* is by far the most widespread, and all the firms interviewed follow this strategy to a greater or lesser extent. Customer relations are thus very important as emphasised by both Hansen & Serin (1997) and Mendonça (2009), and the interviews furthermore underline that close customer relations are getting increasingly important for a majority of the firms.

The ways in which the firms use this innovation strategy are, however, quite different both in relation to the frequency and the mode of contact to the customer. Some firms constantly interact with their customers, while others have more seldom contact. Similarly, face-to-face meetings with customers are very important for some firms, while contact by email or phone is sufficient for others.

These differences primarily depend on the complexity of the products and the derived needs for transferring information and knowledge between customer and producer.

Customisation of products generates nearly the entire turnover for a number of the fabricated metal firms. This is e.g. the case for a firm which is the world leading producer of concrete pipe machines. All products are either unique or produced in a very low volume. A second example is a firm working with processes such as enamelling, polishing and welding. For this firm, 75 % of the turnover is created through the production of customised products, which demands frequent exchange of information with the customers. Yet another example is a manufacturer of stainless steel tanks. This firm only reproduces a previously manufactured tank if a customer needs to have an order repeated, and the batches are furthermore small, typically 1-3 tanks. The contact with the customer is thus very frequent in order to agree on the exact specifications of each individual product:

“Drawings can be exchanged up to 20 or 30 times before the initiation of production if the product is of great complexity.”

Head of Production, small firm.

This underlines the significance of co-operation between firms and their customers, especially in regard to the manufacturing of tailor-made products.

However, the production of customised products does not constitute the majority of the turnover for all the firms interviewed. This can be due to two reasons. Firstly, simple goods can continue to be important in the production line, even though this was only the case for one firm offering a number of metal working processes. 80 % of the orders of this firm is of such standard character, while the remaining 20 % has to be customised, typically as they are part of other products. Secondly, innovations which contain a more radical element were found to be important in a few cases. One example is a firm which is among the leading in the world within the production of stainless steel feet to machines. Although the development of customer-specific solutions is somewhat important, it is

the more radical innovations that are at the core of the firm's business model. Technological progress, within CAD/CAM as well as the improved access to information about products and standards on the internet, has implied that it is becoming increasingly possible for an SME like this firm to engage in such radical innovations. A second prime example is an R&D intensive producer of metal powder and stainless steel products. Two out of three innovations carried out in this firm can be characterised as radical innovations which are basically founded on the ideas and research carried out by the staff. Yet, the relations to customers are still important: the remaining third of the innovations is based on specific customer needs, and the firm has furthermore learned that it is essential to analyse the commercial interest of the radical innovations at an early stage. The firm had a number of previous experiences, where a brilliant new product was a failure, as there was no market for it. This exemplifies the importance of combining the STI mode (research in powder technologies) and the DUI mode (interacting with customers) in order to promote growth at the firm level (Jensen et al., 2007).

The interviews do not indicate that it is primarily the smaller firms that emphasise customer-oriented innovation processes. One of the largest participants in the analysis is a factory producing fittings. Even though manufacturing of standard products is still important for the firm, it is worth noticing that innovation processes are increasingly being led by customer demand, and that customers are involved in nine out of ten new product developments. This emphasises that the technology pull originating from the customers is of great importance even for the largest fabricated metal firms with their own development department.

Finally, innovations through *process specialisation* are also of key importance for the competitiveness of a number of firms – both large and small. Among the large firms is a producer of great steel structures. A crucial area of innovation for this firm is automation of welding processes, which yields great returns due to the scale of the structures constructed. Optimisation of the production methods is for instance imperative in the manufacturing of foundations for offshore windmills. Another

example is a firm to which the fine-tuning of casting processes is central to innovations. The technology of casting is well-known, and few groundbreaking advances are made today. However, this firm develops and builds machinery that allows it to improve the accuracy of the casting process and thereby achieve higher uniformity in the final products. This keeps the need for additional modifications of goods at a minimum.

Improvement of production processes can also be important for other reasons than simply reducing production costs. Developing the quality and the range of services offered is highly important for one of the firms to get access to new markets. Large, potential customers like Deutsche Bahn constantly introduce new requirements and standards that the suppliers must meet. A continuous improvement and certification of skills and capabilities is therefore necessary in order to include and maintain the most attractive customers in the clientele.

The importance of customer and supplier relations for innovation

The previous section underlined the relevance of the innovation strategies defined by Hirsch-Kreinsen (2008) in relation to the fabricated metal firms in the case study area. The customer-oriented strategy was especially widespread, and customisation of products is of major importance for firms irrespective of size. Naturally, customisation occurs differently and the levels of technology are utilised in different ways by the firms, but the process is fundamentally the same: the firms' ability to create and implement solutions to specific needs – often in cooperation with the customers – is essential to the survival of many firms. Close relations to customers are thus of significant importance. The remaining part of this section will focus on linkages to suppliers, as customer linkages were described in detail above.

An innovation strategy closely related to process specialisation, but not directly included as it is defined by Hirsch-Kreinsen (2008), is to purchase capital goods with inbuilt R&D. Firms thereby indirectly benefit from R&D, but they also indirectly pay for it. Use of advanced machinery has previously been identified as an important source of innovation for LMT firms in several studies

(Santamaría et al., 2009; Heidenreich, 2009), and buying machinery from suppliers is also central to the innovation strategies of a considerable number of firms in this survey. This is primarily the case for smaller firms which do not produce any final goods and therefore exclusively work as suppliers. Acquiring the right machinery is absolutely fundamental for these firms, since it may save both time and manpower as well as improve the quality of the work. However, it was emphasised on several instances during the interviews that it becomes increasingly difficult to have an overview of the possibilities offered by the market.

“Both the number of models and the complexity of the machines have increased rapidly during the last years.”

Managing Director, medium sized firm

This highlights the importance of acquiring analytical knowledge for firms with a mainly synthetic knowledge base (Jensen et al., 2007). The ability to match the firm’s needs with the opportunities provided by the market is essential, but it demands considerable technological knowledge.

The fabricated metal firms in the case study area also involve suppliers of innovation processes by forming more or less formalised strategic alliances. Most of these cooperations are informal in the sense that many firms have preferred suppliers whom they trust and have frequent contact with. These firms are chosen due to their flexibility, price and the quality of their products as well as the product equipment they use. Some firms share clientele as they recommend each other to customers when possible. Contact between the firms and the suppliers is very frequent – in some instances daily – in order to coordinate the production processes and agree on issues such as tolerances and choice of materials. The cooperation between firms may develop even further than such informal partnership. One firm has gone as far as signing development contracts with its closest suppliers, which gives the firm exclusive rights to the products or at least advantageous conditions. Consequently, the suppliers are functioning as an ad hoc pool of development staff.

A further way of involving supplier relationships in innovation processes is through outsourcing. The large wage differences between Denmark and Eastern European and especially Asian countries imply that there are large potential benefits related to outsourcing. Realising these potentials can, however, be troublesome due to difficulties associated with language, culture and geographical distance. One of the largest firms thus describes its ability to manage outsourcing as essential to its innovation processes. The experiences gained by the firm through outsourcing to Poland and Turkey are now used in China, and some of the firm's Polish employees have been heavily involved in order to contribute with their perspectives on potential pitfalls.

Competition from low-wage countries

The outsourcing strategy of the firm described above is typical of the low-wage countries' impact on the competitiveness of Danish firms: manufacturing of large structures takes place in e.g. China, while completion and assembling of different parts in addition to manufacturing of smaller goods continue to be placed in Denmark. This pattern also emerges in a number of other interviews. One example is a casting firm which produced batches of up to 500,000 similar pieces to the German auto manufacturing industry in the 1990s, but the production of such simple castings has now been relocated. Another example is a factory producing fittings which is under growing competitive pressure concerning the production of large batches. Therefore, both firms increasingly emphasise manufacturing smaller batches of high quality. An example from the fitting factory is the production of 20 copies of fittings from 1878 used in a recent renovation of Amalienborg, the Danish royal palace.

Despite the competition from low-wage countries, the interviews show that the clear majority of firms do not consider this competition as threatening to their existence; several firms experience that former customers return after having used suppliers in low-wage countries for a while. One of the most important problems associated with sourcing from low-wage countries is that the quality of the products does not reach Danish standards:

“The product quality is often high in the first shipment, average in the second shipment and then strikingly lower from the third shipment.”

Head of Development, small firm

A second problem is the terms, conditions and transaction costs related to production in e.g. China. Usually a Danish firm will pay one third of the price before production starts and the remaining two thirds when the products are shipped off. Total production and delivery time is typically 3-4 months. It was stated in several of the interviews that Danish firms will often be able to produce as cheaply as their Chinese competitors if they are given the same conditions.

A third issue is the need for face-to-face interaction between customers and suppliers. As described previously, most of the fabricated metal firms have very close contact with their customers. This reflects that the majority of the firms have now evolved into producers of higher-ordered goods, which is less footloose than the production of large standardised batches. Communication by phone and email is therefore insufficient, especially considering the language differences. This barrier – as well as the other issues – shields the Danish firms against low-wage competition.

Increasing knowledge content – securing continuing competitiveness

The continuing competitiveness of the Danish fabricated metal industry is very closely related to the firms' ability to increase the knowledge content in their products. Profiting from especially the tacit knowledge held by employees is a necessity in order to continue the development of unique attributes which cannot easily be transferred across geographical distance. The case study has highlighted two different issues which make it difficult for the firms to develop their business in a more knowledge intensive direction:

Questions on *intellectual property rights* come along with the increasing knowledge intensity of products, even when they are primarily based on tacit knowledge. Tacit knowledge is fundamental for most innovation processes in the fabricated metal industry, but the replicability of metal products

is still high once they are developed and disseminated. The protection of products through patents is thus increasingly relevant for fabricated metal firms. It is therefore problematic that the patenting system is fundamentally focused on high-tech industries and radical innovations, while incremental innovations which are typical of the fabricated metal industry do not qualify for patents. It is thus stated as a direct requirement that:

“The invention must differentiate itself significantly from the known techniques on the field.”

(Danish Patent and Trademark Office, 2008, p. 1)

Consequently, many fabricated metal firms have to protect their products through alternative methods. One example is a firm which does not advertise newly developed products. No information about the products can be found on the firm’s webpage, and they are only presented to selected customers who are allowed to purchase them. Another firm benefits from the fact that all material describing the techniques used by the firm is written in Danish and thus hardly accessible for its competitors, who are mainly Japanese.

Even though such strategies may be very effective for the individual firm, they are not optimal or replicable in every case. The mismatch between the patenting system and the innovation strategies of firms working on the basis of a synthetic knowledge base is therefore an important issue to deal with, especially as the knowledge content – and the value of the products – increases.

A second, very important issue is related to the *skill-level of the workforce* in the fabricated metal industry. Successful LMT firms invest in high levels of training for all staff (Corbett, 2008), as the development towards production of goods with increasing knowledge content depends completely on firms’ ability to access a sufficiently skilled workforce. At the time of the interviews (January and February 2009), the majority of the firms did not have problems recruiting the necessary labour, but almost all of them had such problems before the start of the current financial crisis, resulting in

reduced growth rates. A main reason for this appears to be the inability of the educational institutions to provide the students with a sufficiently high level of skills, thus limiting the possibilities for firms to introduce elements from the STI mode in their production processes (Jensen et al., 2007). The problem for institutions offering vocational education is that trades such as smith or welder do not attract the youth with academic abilities, while the fabricated metal firms are increasingly seeking employees with both academic and practical skills. The educational institutions therefore face a dilemma:

- Shall they maintain the current degree of difficulty even though it does not fit the needs of the firms?
- Or shall they increase the degree of difficulty even though a large proportion of the students will not be able to fulfil the demands?

Unfortunately, this dilemma appears to have no easy solution. One vocational school in the region has increased the degree of difficulty, resulting in an increase in the number of failing students. Similarly, another vocational school introduced a new education in metal work targeting the energy sector, but it failed to attract students; presumably due to the relatively large amount of academic content. Thus the education was not established even though firms are seeking employees with this knowledge combination. This clarifies why most of the firms have considerable difficulties getting access to qualified labour during normal economic conditions.

A second problem for the educational institutions is related to the growing capital intensity of the fabricated metal industry. The ability of employees to operate machinery is absolutely essential for the firms' productivity. However, the rapid development of new equipment combined with their increasing sophistication and preciousness imply that the educational institutions are unable to keep up with firms' investments in machinery. This is reflected in the great emphasis that employers place on upgrading of skills and training on the job. A number of firms actually prefer to train the workers themselves. One phrased it in this way:

“Formal education does not have great importance – it can actually be an advantage not to hire someone who has previously been working on a specific machine and who carries with him old habits and routines.”

Managing Director, medium sized firms

These firms stress the importance of characteristics such as flexibility, willingness to learn and a sense of quality rather than the applicants' formal education. It should, however, be noted that a group of other firms emphasise the formal education and only hire people with relevant degrees.

The case study area – localised advantages?

When searching for an explanation for the success of the fabricated metal industry in the case study area, it is first of all relevant to compare the skill-level of the employees with the national average, given the increasing importance of knowledge content in the products of the industry. However, the skill-level in the case study area (table 3) is quite similar to the average of the Danish fabricated metal industry (table 1), even though the share constituted by employees with further education is a bit higher in the case study area. The main difference is with regard to “Long further education”, which constitutes respectively 1.8 % and 1.0 % in the two areas.

TABLE 3 APPROXIMATELY HERE

Thus, the education level of the employees does not explain the positive development in the area. This is, however, not surprising considering the problems of the educational institutions described above. Instead, a number of other features underlined in the interviews appear to be more important.

It is expected that the geographical distance to customers is of great importance to the industry, considering the significance of the innovation strategy that is based on customisation. A number of firms note that the existence of a large pool of customers in the area within the fabricated metal and related industries is crucial. Furthermore, the effect of the location of large firms in the area –

especially Grundfos – is also put forward on several occasions. Some firms, however, also consider the distance to the Triangle Region in the Southern part of Jutland as a disadvantage.

The characteristics of the local labour market also appear to be beneficial for the firms in the case study area. The concentration of metal firms in the area implies that the number of potential employees is high, and people are less hesitant to work in noisy and dirty jobs than elsewhere. The firms thus benefit from a shared pool of labour, as described by Marshall (1890). Furthermore, the wage-level is also an advantage for the firms. The average wage-level in the North Denmark Region – which covers the main part of the case study area – is the lowest of the five Danish regions. Finally, the characteristics of the area's labour force are highly valued by a representative of one of the larger firms. Interestingly, this is not linked with the formal education in the area. Instead, the flexibility and the technical capabilities of the workforce are associated with the rurality of the region. Overall, the availability of a relatively cheap and large labour force with a traditional focus on practical skills and flexibility hence appears to be one of the assets of the fabricated metal industry in the case study area.

Tradition and the characteristics of the workforce also influence the entrepreneurial spirit, which seems to be highly valued in the area. It was stated by managing directors on several instances during the interviews that the growth of their businesses is their personal responsibility, and they do not expect the government to provide much help.

“It is a point of honour for me to have a healthy firm which minds its own business.”

Managing Director, medium sized firm

This professional pride is also reflected in the weight given to the manufacturing of quality products. The extent to which the firms emphasise this aspect is interesting to note. Nearly all 17 firms were described as producers of quality goods, and eight of the firms were directly described as differentiating themselves from other Danish firms by their emphasis on quality.

“One of the main strengths of this firm is the emphasis on quality – our prices are quite high, but it pays off.”

Head of Department, medium sized firm

This trade-off between quality and price is found in a number of other firms. It is notable the extent to which this issue is underlined in the interviews, even though it should be taken into consideration that managers are likely to have a biased opinion with respect to the quality level of their products.

Summing up, the analysis shows that the existence of a large local market and the presence of a high number of metal workers with a tradition for physical and practical work, combined with an independent and quality-focused attitude are of main importance in order to explain the development of the fabricated metal industry in the case study area. Conversely, contact to knowledge institutions as well as governmental programs and initiatives have, at best, a marginal importance for the majority of the firms. These issues will be considered in the concluding discussion.

Room for LMT industries in Denmark? Discussion and conclusion

The analysis presented in this paper underlines that the size and economic importance of LMT industries is substantial and stable. The analysis furthermore clarifies the ways in which LMT firms innovate and remain competitive in a globalised economy. The recipe is founded on a clever exploitation and development of the synthetic knowledge base in the firms. This knowledge base enables undertaking a number of different innovation strategies, which are essential in the efforts to fight off competition from low-wage countries. Despite this, most political interest is still directed towards high-tech industries (see e.g. Hirsch-Kreinsen, 2005; Jacobson & Heanue, 2005 and Turok, 2004), which are seen as representing the future of economic activity in the western world. Recently, more inclusive views on innovation, which consider the DUI mode of innovation, have, however, been promoted by some policy makers. An example of this is the national innovation strategy adopted by the Finnish government in 2008 (Finnish Council of State, 2008), which recognises that innovation policies have so far exaggerated the focus on development and commercialisation of new technologies. The strategy furthermore specifically emphasises the need for a *broad-based innovation strategy* that also encompasses a significant orientation towards the demand of customers, even though a recently prepared evaluation criticises the impreciseness of the notion and the mechanisms whereby such a broad based innovation strategy shall be achieved (Edquist et al., 2009). Similarly, a policy report published by the European Commission highlights the necessity of recognising the different knowledge bases of firms and not solely preparing policies targeting firms with an analytical knowledge base, as “*knowledge and innovation should not simply be equated with R&D*” (European Commission, 2006; p. 25).

Still, other EU publications continue to stress the overwhelming importance of R&D. Recent examples include the innovation scoreboards (see Hollanders et al., 2009 and Jensen et al., 2007) and the process of producing indicators for monitoring the development of the European Research Area,

where it is evident that a knowledge-based economy is considered very closely linked to the significance of R&D (European Commission, 2009).

To a large extent, the overwhelming policy focus on high-tech industries can also be found in the interest in academia, even though some research centres take a broader view on innovation, e.g. UNU-MERIT (see for instance Arundel and Kemp, 2009 and Goedhuys et al. 2008) and the institutions involved in the EU funded PILOT (Policy and Innovation in Low-tech) project (Hirsch-Kreinsen et al., 2006). Still, these studies are hardly comparable in numbers to the numerous studies of high-tech sectors, such as biotech and ICT, which are constantly carried out. The problem is not the amount of these papers – the problem is that studies of LMT industries are much scarcer. Ignoring these industries will eventually reduce the concept of innovation to only encompass the types of innovations which take place in high-tech industries. This will further increase the focus on promoting conditions for firms working from an analytical knowledge base and reinforce the imbalanced attention given by politicians to high-tech industries. An important consequence is that little consideration is given to the development of peripheral and rural regions, which are unable to attract these R&D intensive industries.

This paper demonstrates that such focus on high-tech industries is flawed, as it ignores the huge importance and potential of LMT industries even in a high-wage country as Denmark. This is mirrored in the interviews carried out for this project, where dissatisfaction with the Danish government's policies towards the fabricated metal industry is prevalent. The feeling among most firms is that they have to look after themselves:

"The growth taking place in fabricated metal firms is solely due to the firms themselves. There are many other trades and industries which are more eye-catching than the fabricated metal industry."

Head of Production, small firm

In this way, the competitiveness of the fabricated metal industry is not seen as a topic the politicians care about – at least not until the firms start firing people and the large economic importance of the industry becomes obvious. Based on the interviews, three key target areas for political action have been identified:

- Improve the quality and attractiveness of the relevant educations
- Promote cooperation between firms and knowledge institutions
- Introduce innovation policies targeting LMT innovation processes

The interviews clearly show that the most serious consequence of this attitude is linked to the skill-level of the workforce. The inability of the technical schools to provide the students with skills that satisfy the needs of the fabricated metal firms threatens the future supply of qualified labour.

Increasing the attractiveness of the technical schools and the educations relevant for the fabricated metal industry should be a priority for the politicians. The main problem, which has so far been politically ignored, is the low prestige of these educations. Changing this situation demands action all the way down to elementary school where the foundations for these attitudes are laid, but it is interesting to note that the same mechanisms can also be found at the university level. The most R&D intensive firm included in the analysis thus has problems recruiting people with master degrees, as most students focus on biotech, nanotech and cleantech today. Thus **a key recommendation** on the basis of this analysis is that politicians should encourage students' interest in the fabricated metal industry, rather than treating it as if it has little future in Denmark. This will allow LMT firms to apply aspects of the STI mode in their production processes, following Jensen et al. (2007).

Related to the issue regarding the skill-level of the workforce is the importance of the knowledge institutions for the industry. The case study shows that there is very limited contact between the firms in the area and the local universities, even though quite a large share of the firms would find it interesting to build a closer relationship. The universities are mainly potential partners when it

comes to projects focusing on process innovation or step-by-step innovation, for instance reducing emissions from combustion plants through the use of simulations.

It can be argued that the lack of contact to the knowledge institutions is not surprising – or of great importance – considering the fabricated metal industry being an LMT industry. On the other hand, the demand for increasing knowledge content in the products of the fabricated metal industry implies that such contacts become more and more important for Danish firms in order to remain competitive:

“Hopefully, the contact to universities will intensify in the future – it is a necessity to capitalise on the strengths of the Scandinavian welfare state in order to make up for the higher labour costs.”

Engineering Director, medium sized firm

Previous research shows that LMT firms primarily cooperate with local universities (Teixeira et al., 2008), and a **second recommendation** is thus to facilitate collaborations between geographically proximate knowledge institutions and fabricated metal firms. Such cooperation can increase the knowledge content in the products, and it is, furthermore, important that Danish fabricated metal firms make use of the high quality of Danish universities in order to compensate for the advantages enjoyed by firms elsewhere.

Similarly to the lack of importance of cooperation between firms and knowledge institutions, governmental policies appear to have a marginal impact on the firms' competitiveness in the case study area. Many of the firms do not consider the available initiatives relevant to them, and only two out of the 17 firms have used some sort of governmental program within the last couple of years. The limited use of governmental initiatives is supposedly partly due to a lack of knowledge about the available offers, but the content of the initiatives is also likely to carry a large part of the responsibility. In this respect, two points should be emphasised:

The first problem is related to the types of innovation processes. Many programmes require that applicants can make it probable that the resulting innovations will be more or less radical. This is rarely the case for innovations in LMT industries, as the clear majority of innovations are incremental or based on the acquisition of capital goods, as shown in this as well as other research projects (Santamaría et al., 2009; Heidenreich, 2009). Furthermore, it may actually be difficult to describe the objective of the innovation process for firms following the innovation strategies oriented towards the customers or step-by-step innovations. The consequence is that the firms are unable to apply for the programs:

“We do not get any help, but it should be said that we have never applied for it. It is hard to describe innovation projects, because the customers are most often not sure how the final product should be – and this information has to be stated in the applications.”

Head of Development, large firm

A second problem is that none of the available programs focus on the innovation processes that take place between seller and customer. The small, easy accessible initiatives offered by the Danish Agency for Science, Technology and Innovation such as “Knowledge Coupon” and “Knowledge Pilots” are either targeting innovative cooperation between a firm and a knowledge institution (the first) or innovation internally in a firm (the second).

A third recommendation is, therefore, that the Danish government should adopt a broader view on innovation similar to the one found in the Finnish National Innovation Strategy, including initiatives which give higher priority to incremental innovations and innovations based on the acquisition of capital goods. It is, for instance, suggested in one of the interviews that it would be very helpful if the government introduced new products and markets, as smaller firms do not have the resources to prioritise this in everyday life. It is important to remember that the potential benefits of improving the conditions for LMT firms are very large, considering the great economic importance of LMT

industries. Changing the way government views and promotes innovation is therefore expected to yield more benefits than costs.

The fundamental argument, which is promoted in this paper, is that it is possible for Danish LMT industries to be competitive, despite the lack of political attention given to them. There is, however, no guarantee that this will be the case onwards, considering the global competition and the increasing skill-level of the populations in especially Asian countries. Politicians cannot take for granted that e.g. the fabricated metal industry will remain competitive when the governmental support structure is based on the needs of high-tech industries. Nor can it be taken for granted that an adequate supply of labour will be available when it is not a political priority to encourage youth to pursue a career within the metal industry. It is thus a necessity to adopt policies which take the needs of LMT industries into account in order to strengthen the competitiveness of Danish LMT firms. A detailed knowledge of how innovation processes take place in these industries is a precondition for such successful policymaking. Hopefully, this paper has offered a contribution in this respect.

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