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# **Human Capital in Low-Tech Manufacturing: the Geography of the Knowledge Economy in Denmark**

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## **ABSTRACT**

An essential feature associated with the rise of the knowledge economy has been the increasing focus on the importance of human capital as a precondition for economic growth. Human capital has been found to have a positive impact on economic growth of high-tech industries, however, the influence of human capital on the development of low-tech industries is yet to be analysed. This paper provides such an examination of low-tech industries based on an analysis of employment data within manufacturing industries in Denmark in the period 1993-2006. The findings highlight, firstly, that human capital appears to be equally important for economic development in low-tech industries and, secondly, that the divide between the large urban regions, especially Copenhagen, and the rest of the country plays the primary role in explaining the geography of human capital. These findings stress the relevance of a broad conception of the knowledge economy which goes beyond high-tech industries.

## **KEYWORDS**

Human capital, low-tech manufacturing, Denmark, knowledge economy, highly skilled labour, urban and regional development

## INTRODUCTION

This paper is concerned with human capital in low-tech industries. Currently, human capital is regarded as essential to development of the high-tech sector in Europe. These are industries that often rely on highly analytical knowledge bases (Asheim, 2007), i.e. science based knowledge and formal R&D innovation, and they are considered to be crucial engines of economic growth and competitiveness in the western world (Pisano & Shih, 2009). Further, the high-tech industries have been found to be predominately concentrated in large city regions (Andersen et al., 2010). However, little is known of the development and geography of human capital in low-tech manufacturing industries that are geographically concentrated outside the main growth regions, even though knowledge production and innovation is important in these industries too (Bender & Laestadius, 2005; Hansen & Winther, 2011b). Thus, it is interesting to analyse the use of human capital over time in low-tech industries, compared to more R&D-intensive industries, where human capital has been found to have a positive influence on economic development (e.g. Murphy & Siedschlag, 2011).

In this paper we focus on manufacturing distinguishing between high-, medium-, and low-tech industries. Following Lundvall & Johnson (1994) and Asheim (2007) that argue for a broader understanding of the knowledge economy the main objective of the paper is to examine the use of human capital over time in low-tech industries and thereby challenge the close relationship between human capital and high-tech industries that is often taken for granted in literature and policy documents (e.g. OECD, 2004b; Balconi *et al.*, 2007; Acs & Megyesi, 2009). Accordingly the paper examines two interrelated issues. First, we compare the change in human capital levels in high-, medium-, and low-tech industries in Denmark to assess the importance of highly skilled labour in non-research intensive industries. Second, we analyse the locational dynamics of highly skilled labour to grasp the development of geographical differences from 1993 to 2006 to examine if the location of human

capital in low-tech industries is different from the urban concentration of human capital in high-tech industries.

The paper is structured as follows. The theories on human capital are outlined in the second and third sections with a specific focus on the emphasis in the literature on the relation between human capital and high-tech industries. The subsequent section briefly describes how this connection has been adopted by policymakers. The fifth section presents the data and methodology, while the sixth section presents the analysis of the locational dynamics of human capital within different types of manufacturing industries. The final section concludes and discusses the findings.

## **HUMAN CAPITAL AND GROWTH**

In the knowledge economy, understood as the result of the faster diffusion of knowledge due to advances in information and communication technologies and the increasing long term knowledge intensity of the economy (Amin & Cohendet, 2004), human capital, i.e. the competence and skills of people to perform as labour, is seen as a key resource. In mainstream economics, especially endogenous growth theories have applied human capital as an explanatory factor of long term economic growth (Lucas, 1988; Romer, 1990). In these models human capital is included in the production function in various ways to explain long term economic growth. In Romer's (1990) model, growth results from accumulated technology depending on human capital levels. The theory of Lucas (1988) considers the process of human capital formation as the engine of growth – economic growth is considered a result of human capital growth. In urban and regional studies two main perspectives associated with the work of Edward Glaeser and Richard Florida have embraced human capital as an important category in explaining urban and regional growth.

Edward Glaeser's work on human capital remains within the framework of mainstream economics in its analysis of city growth in the US. In these studies human capital is measured as formal education and the results of the econometric analyses show that human capital levels are associated with urban economic growth and can explain the variation between cities (Glaeser, 1994; Glaeser & Saiz, 2004). A further important conclusion is that cities with high levels of human capital are more likely to further attract highly skilled labour (Berry & Glaeser, 2005). Hence, production, attraction and retention of human capital become crucial for cities to grow. Glaeser has moved on to examine the influence of a variety of factors including amenities, climate and consumption opportunities on cities' human capital levels (Glaeser *et al.*, 2001; Glaeser, 2005; Glaeser & Gottlieb, 2006). A main conclusion of the latter works is that if cities are to remain economically successful they must attract highly skilled workers on a basis of quality of life, higher wages and, if possible, a pleasant climate.

In a similar line of work, Florida (2002; 2003; 2005) considers the creative class an essential prerequisite for regions and large cities in a knowledge economy. The creative class produces new knowledge or combine existing knowledge in a new way that leads to regional economic growth, as new knowledge holds the potential of higher levels of innovation and entrepreneurship (Lee *et al.*, 2004). While Florida and Glaeser has brought attention to critical aspects of the relationship between regional growth in large cities and human capital, the attention given to amenities has been contested by especially geographers writing from an evolutionary and institutional perspective Peck (2005); Pratt (2008); Storper & Scott (2009); Hansen & Winther, 2011a).

In this paper we address the importance of human capital for low-tech manufacturing industries that are concentrated in regions outside the main urban areas (see McGranahan *et al.* (2011) for an analysis of the effect of talents on growth in rural areas) in contrast to the large city focus of Glaeser and Florida. The importance of human capital has been thoroughly examined for high-tech industries,

resulting in the widespread understanding that human capital is particularly important for these industries. However, below we question this relationship by examining the importance of human capital in low-tech industries.

## **HUMAN CAPITAL AND THE HIGH-TECH SECTOR**

The relationship between highly skilled labour and development of high-tech industries has been the focus of an important strand of the human capital literature (e.g. Zucker *et al.*, 1998; Murphy & Siedschlag, 2011) and various studies focus on the relationship between highly skilled labour, migration and high-tech entrepreneurship (e.g. Wadhwa *et al.*, 2008; Hart & Acs, 2011). In the work of Florida (2002; 2003), the relation between the creative class and high-tech industries is even more pronounced. Florida's (2002) main argument is that new communities characterised by weaker ties and greater diversity promote the development of high-tech industries. High-tech industries have superior growth rates in "creative-class regions", where the lifestyle and diversity attract the creative class that primarily works in high-tech sectors, financial services and the healthcare sector. Thus, Florida presents a circular argumentation: the presence of high-tech industries is both an important part of the conditions for attracting the creative class, and a main effect of having a concentration of creative individuals. Further, Florida does not explain the importance of the creative class for low-tech manufacturing industries, but focuses on industries with high R&D-intensity. He maintains this focus in his work on Europe. Florida & Tinagli (2004) stress how the ability of European countries to maintain and attract talent allows these countries to catch up with the US in terms of technological development and growth in high-tech industries.

The close link between highly skilled labour and high-tech industries has been widely embraced within academia (e.g. Balconi *et al.*, 2007). Analysing the US high-tech sector, Bieri (2010) con-



cludes that the distribution of high-tech activity is becoming more unequal, and the positive influence of creativity on the formation of high-tech firms is significant, also relative to increased university spending on R&D. Frenkel (2012) finds that human, social and creative capital have positive influences on the location of high-tech firms, and draws the conclusion that regional policymakers ought to strengthen these assets to attract high-tech firms. Similarly, Chen & Karwan (2008, p. 255) state that “It is essential for cities and MNEs to adopt innovative ways to continue to attract and retain high-tech employees from pivotal talent pools”. A clear example of an academic paper arguing for a policy focus on the creative class and high-tech industries is the study of Baltimore by Acs & Megyesi (2009). According to them, attracting the creative class is central to the development of high-tech industries which again promotes the transition from an industrial economy to a knowledge-based economy, thus, allowing city regions such as Baltimore to survive and grow despite increasing global competition. Looking to high-tech areas such as Silicon Valley, Seattle and Boston Route 128, the policy recommendation of Acs & Megyesi (2009, p. 437) in the case of Baltimore is to “go for a quick fix by attracting talent” rather than focusing on the improvement of basic skills and a long-term emphasis on education. Whether such policy advice is well-founded and applicable to especially a city with a strong industrial tradition as Baltimore can be questioned, but it is a fact that the competition for highly skilled labour is a main topic among public policymakers today.

## **HIGHLY SKILLED LABOUR AND PUBLIC POLICY**

In terms of policymaking, there is a general emphasis on high-tech industries in a European context (Hirsch-Kreinsen, 2005; Hansen, 2010; Hansen & Winther, 2011b). Therefore, it is not surprising that the connection between human capital and high-tech industries has been adopted by decision

makers (OECD, 2004b). In addition to the increasing importance of the knowledge economy, the competition for highly skilled labour has also intensified due to the declining ability of most western countries to produce a sufficient supply. Considering the rising demand for highly skilled labour in developing countries such as India and China, which today are net contributors to the talent pool, there is little hope that the competition will decrease in the years to come (Papademetriou *et al.*, 2009b). The public sector's role in the highly skilled labour contest has increased, and focus is often on the conditions of high-tech industries. When the German Green Card initiative failed to attract the expected numbers of engineers and IT experts despite preferential treatment of applicants with a certain education or salary level it was abolished after just three years in 2003 (Collett & Zuleeg, 2008). Elsewhere, policy measures targeting high-tech sector in a more direct way have been applied. In the case of New Zealand, residence permits are more easily obtained by people holding an offer of skilled employment within a "future growth area" being biotech, information and communications technology or creative industries (Immigration New Zealand, 2010). Similarly, the introduction of "strategic growth visas" to investors and persons in "critical industries" such as biomedical research has been suggested in the US (Meissner *et al.*, 2006, p. 40), perhaps combined with privileged access to employment in industry clusters (like Silicon Valley), specialised in specific sectors (Papademetriou *et al.*, 2009a). Finally, Chen & Karwan (2008) describe how the Chinese government relaxes regulation under certain conditions, e.g. allowing the creation of churches despite the official atheist policy when it is considered important for attracting high-tech talent.

As the analysis in this paper focuses on the dynamics of human capital in Denmark, it should be noted that the Danish policies towards attraction of highly skilled labour is not explicitly related to the high-tech sector (Mosneaga & Winther, 2013). The immigration policy contains a so-called "positive list" of occupations with easy access to the Danish labour market, but it is not particularly oriented towards R&D-intensive industries. For the Capital Region of Denmark, attraction and re-

tention of highly skilled labour and talents is a key priority, as it is seen as crucial for the development of a technology-based economy (The Capital Region of Denmark, 2008). However, at the municipality level, the City of Copenhagen stresses that attraction of highly skilled labour is crucial for various innovation processes, including continuous improvements of products and processes, and not just knowledge creation within “nano and bio” (City of Copenhagen, 2007, p. 1). Overall, the emphasis on the importance of highly skilled labour specifically for high-tech industries appears to be less pronounced in Denmark than in other countries.

## **METHOD**

The analysis is based on register data from Statistics Denmark. The data consists of both employment and formal educational for the 275 Danish municipalities (the administrative structure used before 2007) on a 2-digit industry level according to the statistical classification of economic activities in the European Community (NACE), as it is defined by Statistics Denmark (2002). Data is available for the years 1993, 1996, 2002, 2004 and 2006, which covers the most recent period of economic growth and the rise of the knowledge economy in Denmark before the global economic downturn in 2008 (Nissen & Winther, 2008). For some analyses the municipal data is aggregated to county level to describe the larger regional developments.

We differentiate between industries according to the OECD’s classification of technological intensity based on the ratio of R&D expenditures to the output value of the individual industries (see table 1). Unfortunately, our data is restricted to the 2-digit level, while the OECD taxonomy distributes NACE-groups 24 and 35 among several categories. We have assigned both industries (NACE 24, Chemical industries including Pharmaceuticals and NACE 35, Other transport equipment including Shipbuilding and Aerospace) to the medium high-tech category, thus, underestimating employment

in the high-tech and medium low-tech categories. This is especially important to consider in the following analysis in terms of the high-tech sector which experienced growth over the period within pharmaceuticals, which is here part of NACE-group 24.

**Table 1. Manufacturing Industries classified according to R&D Intensity – NACE-code in brackets.**

High-tech	Medium high-tech
<ul style="list-style-type: none"> <li>• Office machinery and computers (30)</li> <li>• Radio, television and communication equipment and apparatus (32)</li> <li>• Medical, precision and optical instruments, watches and clocks (33)</li> </ul>	<ul style="list-style-type: none"> <li>• Chemicals and chemical products (24)</li> <li>• Machinery and equipment not elsewhere classified (29)</li> <li>• Electrical machinery and apparatus not elsewhere classified (31)</li> <li>• Motor vehicles, trailers and semi-trailers (34)</li> <li>• Other transport equipment (35)</li> </ul>
Medium low-tech	Low-tech
<ul style="list-style-type: none"> <li>• Coke, refined petroleum products and nuclear fuel (23)</li> <li>• Rubber and plastic products (25)</li> <li>• Other non-metallic mineral products (26)</li> <li>• Basic metals (27)</li> <li>• Fabricated metal products, except machinery and equipment (28)</li> </ul>	<ul style="list-style-type: none"> <li>• Food products and beverages (15)</li> <li>• Tobacco products (16)</li> <li>• Textiles (17)</li> <li>• Wearing apparel; dressing; dyeing of fur (18)</li> <li>• Tanning, dressing of leather; manufacture of luggage (19)</li> <li>• Wood and of products of wood and cork, except furniture articles of straw and plaiting materials (20)</li> <li>• Pulp, paper and paper products (21)</li> <li>• Publishing, printing, reproduction of recorded media (22)</li> <li>• Furniture; manufacturing not elsewhere classified (36)</li> <li>• Recycling (37)</li> </ul>

*Source: Modified from OECD (2004a)*

Human capital and talent are contested terms in the academic literature. We follow Glaeser (1994) who uses formal education as a measure of human capital, rather than Florida (2002) who defines talent as people who are employed in creative occupations and who are innovative in their everyday work. However, empirical evidence from Denmark and Sweden provided by Hansen (2007) indicates that Glaeser's and Florida's categories are significantly correlated in a Scandinavian context. Analysing data from 2002, the  $R^2$  between the creative class and human capital is 0.852 in Denmark and 0.935 in Sweden. Thus, in our study human capital in the form of highly skilled labour is measured as the share of employees with formal education equalling bachelor's degree, master's degree and PhDs, equivalent to ISCED categories 5A and 6 (UNESCO, 1997).

## ANALYSIS

### **Context – the Danish manufacturing sector**

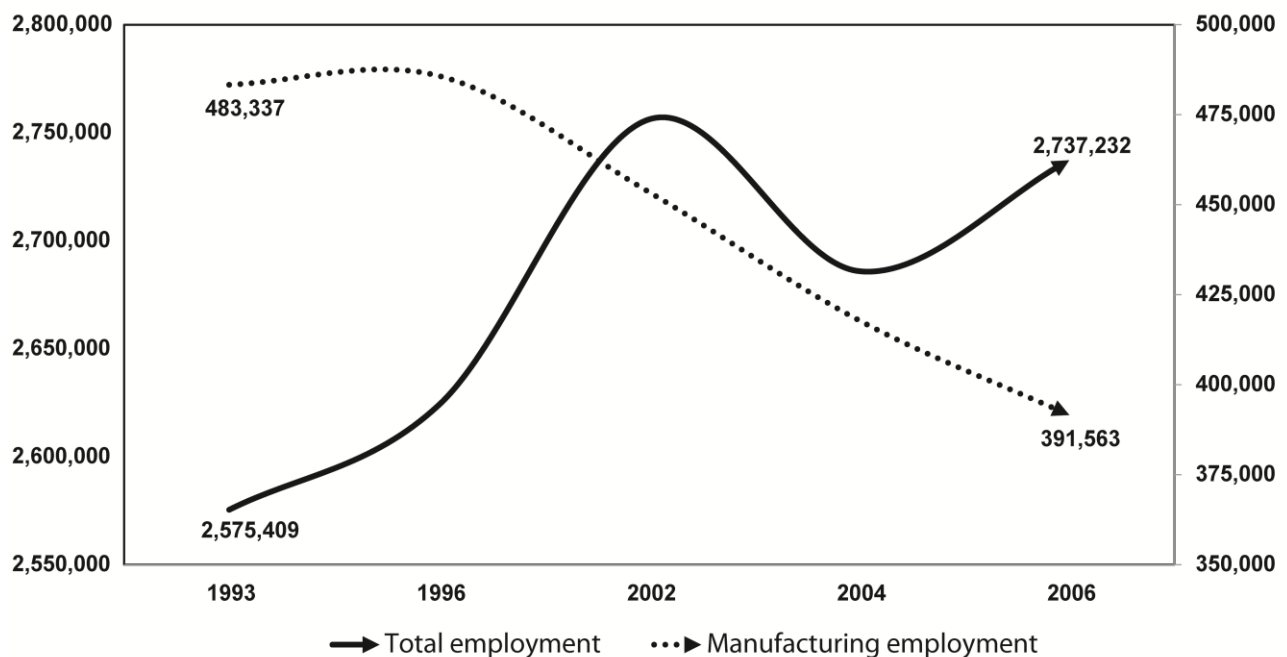
Since the economic resurgence began in the early 1990s there has been a strong transformation of the economy and industrial structure in Denmark towards a service and knowledge economy. Despite the long period of deindustrialisation, manufacturing remains, however, an important sector in Denmark in terms of for instance export and employment (Hansen & Winther, 2012). The manufacturing sector is largely dominated by low- and medium-tech industries such as the food processing industry that accounts for close to 50 % of the employment in the low-tech sector in 2006 followed by the wood and furniture industry and the fabricated metal industry. Among the more R&D intensive industries the machinery industry producing everything from machines for clay-pigeon shooting to high-tech laboratory equipment, is another important specialisation in Danish manufacturing.

Today, the economic growth and job creation is concentrated in the two main urbanised areas in Denmark (Hansen & Winther, 2012): the Greater Copenhagen region and the region around the second largest city, Aarhus – see figure 2. The current spatial dynamics with two dominant regions are markedly different from the spatial dynamics of 1970s and 1980s. The crises in the 1970s and the long period of transformation and restructuring of the economy gave rise to several new industrialised spaces based on a variety of manufacturing industries in Denmark, especially in small and medium sized cities outside the large urbanised areas, often located in peripheral regions of Jutland (Maskell, 1986; Jensen-Butler, 1992). At the same time, the largest cities in Denmark including the Copenhagen inner city were suffering severe job losses and high unemployment rates largely because of a strong de-industrialisation process in traditional manufacturing industries (Andersen & Winther, 2010). Since the early 1990s, however, there has been a resurgence of the large cities in Denmark in terms of growth in jobs and population, including Copenhagen inner city (Engelstoft et

al., 2009; Andersen & Winther, 2010; Andersen et al., 2011). Recent data reveals that this spatial pattern is persistent even after the economic crisis in 2008 (AE, 2009).

The manufacturing sector in Denmark has experienced a major decline in the number of employees as in most other Western European countries in past decades. The deindustrialisation is a result of increased price competition and outsourcing of production to low wage countries and the general trend towards a more service and knowledge based economy. Figure 1 shows that Denmark lost more than 90,000 jobs within the manufacturing sector in the period examined. In the same period, total employment rose by more than 160,000. This growth is mainly driven by various producer and business services, the public sector and creative industries (Hansen & Winther, 2007).

**Figure 1. Employment change in Denmark 1993-2006**



*Source: Statistics Denmark & own calculations*

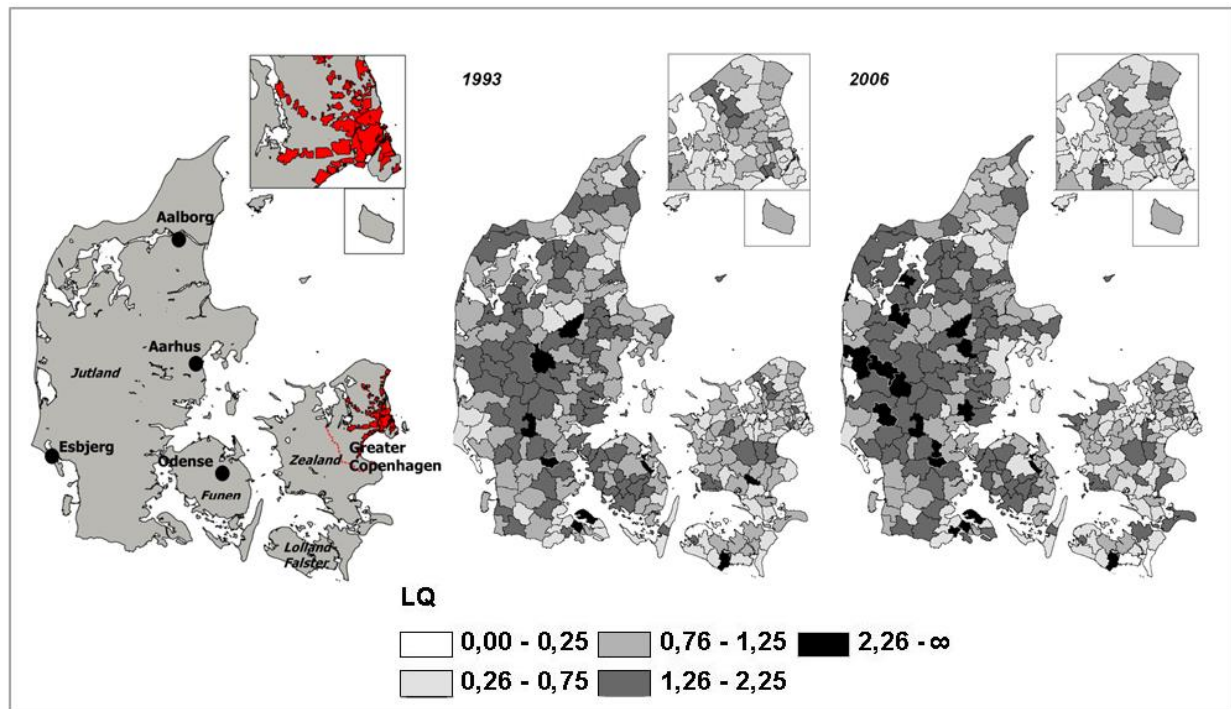
However, the manufacturing jobs and the deindustrialisation processes are not evenly spread geographically. There is concentration of manufacturing jobs in the western part of Denmark, speci-

cally in the middle and western parts of Jutland, but also in large parts of Funen and some parts of Zealand. Thus, there is a clear rural/urban divide in the location of manufacturing employment with the jobs being predominantly located in the rural parts of Denmark, i.e. outside the main city regions and urban growth areas. This is confirmed in figure 2 that shows the location quotient (LQ)<sup>1</sup> of manufacturing employment by municipality in 1993 and 2006. It is clear that this divide between the large city regions and the more peripheral regions has become more profound between 1993 and 2006. Manufacturing is getting less important in Greater Copenhagen as well as in the following four major cities in Denmark; Aarhus, Odense, Aalborg and Esbjerg. A number of municipalities outside the city regions continue to have a specialisation in manufacturing jobs, some even with a marked increase in the number of jobs (in other cases increasing LQs result from slower job loss than the country as a whole).

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<sup>1</sup>  $LQ = (a_x/c)/(b_x/d)$ , where  $a_x$  is local employment in industry  $x$ ,  $c$  is total local employment,  $b_x$  is Danish employment in industry  $x$  and  $d$  is total Danish manufacturing employment.  $LQ = 1$  indicates an average concentration of the industry,  $LQ < 1$  indicates under-representation and  $LQ > 1$  indicates over-representation.

Figure 2. Map of Denmark and LQ of manufacturing employment



Dotted line marks the functional region of Greater Copenhagen; area marks the built-up land

Source: Statistics Denmark & own calculations

To differentiate between the changes in employment according to R&D intensity, table 2 takes 1993 as the point of reference. The table reveals that the job loss is considerable higher in low-tech industries than in the other three categories with the number of jobs in 2006 being only 70 % of that in 1993. Medium high-tech industries have experienced a job loss of only 6 %. This can be ascribed to the fact that medium high-tech industries include pharmaceuticals and wind turbine industries which both experienced considerable economic growth in the last 15-20 years (Valentin & Jensen, 2002; Garud & Karn  , 2003).

Table 2. Change in employment and share of manufacturing employment 1993-2006

	1993	1996	2002	2004	2006
<i>Change in employment (1993 = index 100)</i>					
Low-tech	100	97	85	79	70
Medium low-tech	100	102	99	91	88



<b>Medium high-tech</b>	100	106	103	96	94
<b>High-tech</b>	100	102	104	91	85
<b>Manufacturing total</b>	100	101	94	86	81
<i>Share of jobs within manufacturing (%)</i>					
<b>Low-tech</b>	47.1	45.3	42.7	42.8	40.8
<b>Medium low-tech</b>	19.8	20.0	20.9	20.8	21.4
<b>Medium high-tech</b>	27.3	28.8	29.9	30.3	31.6
<b>High-tech</b>	5.8	5.9	6.5	6.2	6.1
<i>Source: Statistics Denmark &amp; own calculations</i>					

This development has of course had an effect on the share constituted by each R&D category in the manufacturing labour force. As table 2 shows low-tech industries still accounts for 40.8 % of manufacturing employment in 2006 despite the massive job loss within these industries. Medium low-tech makes up 21.4 % in 2006 whereas medium high-tech's share is 31.6 %. High-tech industries only increase their share by 0.3 % in the period and account for 6.1% in 2006. Thus, Danish manufacturing employment continues to be primarily within non-R&D intensive industries.

### **Human capital levels in manufacturing**

There has been a strong growth in the employment of highly skilled labour in Denmark in the past decades with an increase of close to 90 % between 1993 and 2006 while total employment only grew with close to 6 %. Hence, the share of highly skilled labour has increased markedly and accounts for 8.5 % of total employment in 2006 (Hansen & Winther, 2012). There is a distinct uneven geography of highly skilled labour. Highly skilled labour is predominantly located in the Greater Copenhagen region and partly in the city of Aarhus, the second largest city. This urbanisation of highly skilled labour has become even more profound between 1993 and 2006 (Hansen & Winther, 2010).

The growth of highly skilled labour can also be found in manufacturing. Table 3 illustrates the development in the share of highly skilled labour in manufacturing industries. From 1993 to 2006 the

share more than doubles from 2.4 % to 5.6 % and it is important to emphasise that the increase is not just due to highly skilled jobs disappearing at a slower rate than low skilled jobs. In fact, the number of highly skilled workers in absolute figures rose by 88 % from roughly 10,800 in 1993 to roughly 20,300 in 2006 which is a growth rate comparable to the increase of highly skilled labour in economy as a whole.

**Table 3. Growth in the share of highly skilled labour 1993-2006 (1993 = index 100). Percentages in brackets**

	1993		1996		2002		2004		2006	
<b>Low-tech</b>	100	(1.7)	130	(2.3)	194	(3.4)	214	(3.7)	258	(4.5)
<b>Medium low-tech</b>	100	(1.3)	121	(1.5)	150	(1.9)	180	(2.3)	196	(2.5)
<b>Medium high-tech</b>	100	(3.5)	120	(4.2)	174	(6.1)	212	(7.4)	239	(8.4)
<b>High-tech</b>	100	(5.9)	119	(7.0)	127	(7.4)	151	(8.9)	186	(11.0)
<b>Manufacturing total</b>	100	(2.4)	125	(3.0)	174	(4.1)	204	(4.9)	238	(5.6)

*Source: Statistics Denmark & own calculations*

A key issue is whether this increase in the share of highly skilled labour is confined to research intensive industries or a characteristic of manufacturing industries in general. Table 3 shows that the share of highly skilled labour is markedly higher in medium high- and high-tech compared to low- and medium low-tech industries during the entire time period reaching 8.4 % and 11.0 %, respectively, in 2006. It is also evident that the share of highly skilled labour is consistently higher in low-tech industries than in medium low-tech industries. This is in itself an interesting finding which highlights the inadequacy of determining technological intensity solely on levels of R&D investments. An explanation to the difference between the two types of industries might be that while medium low-tech industries gain their innovative capacity through the employment of craft workers with vocational education, the reliance on workers with only primary education in the low-tech industries necessitates the employment of some highly skilled to lead the innovation processes in the firms. In fact, table 3 also shows that the growth in the share of highly skilled labour is highest in the low-tech industries – more than 2.5 times higher in 2006 compared to 1993. Paired sample t-

tests reported in appendix A show that the growth in the low-tech industries' use of highly skilled labour is significantly higher than the three other types of industries. Further, no significant differences are found between the medium low-, medium high- and high-tech industries.

Summing up, this clearly indicates that the employment of highly skilled labour in manufacturing is not limited to the R&D intensive high-tech and medium high-tech sectors. While the share of highly skilled labour in the low-tech industries is still below the average of manufacturing as a whole, the gap to the high-tech industries is decreasing over time.

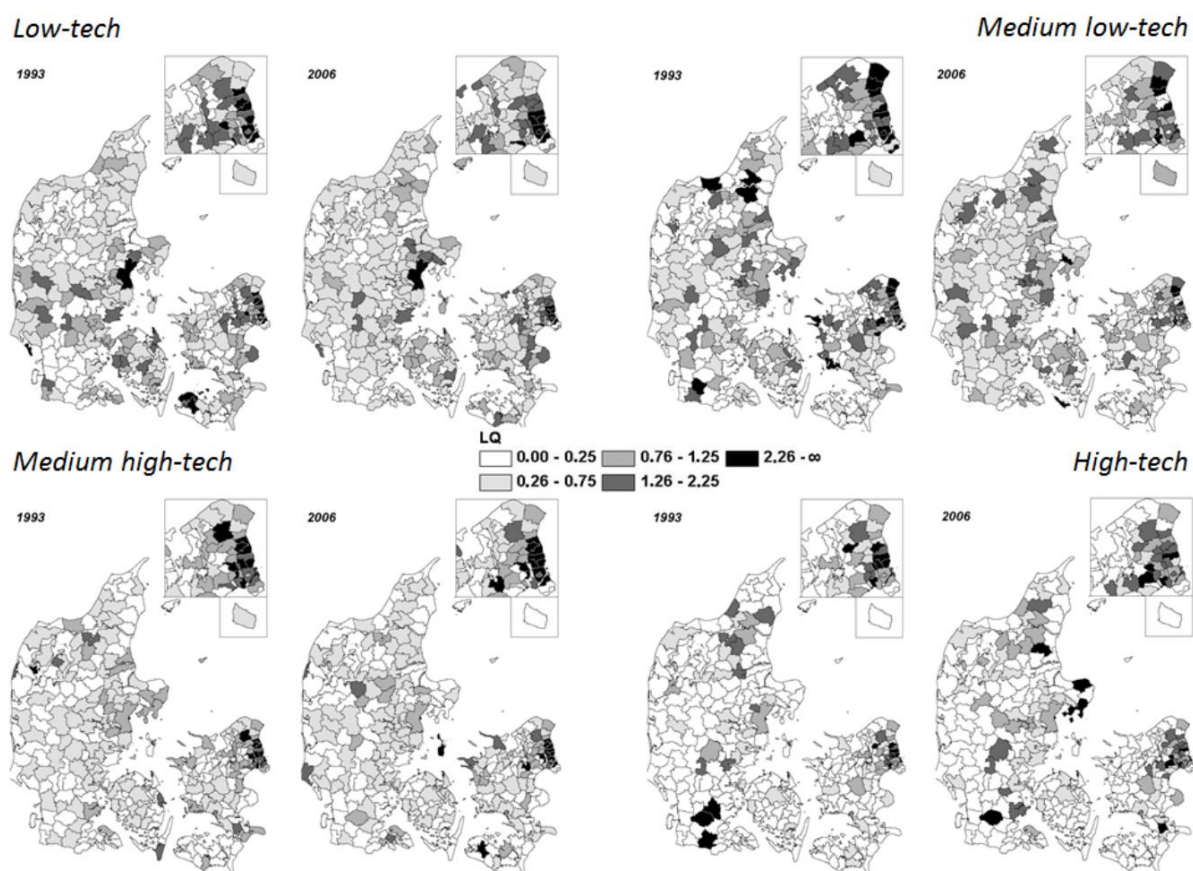
Recent case studies suggest that these findings may be explained by various factors depending on industry, technology level and product specialisation (Hansen & Mortensen, 2006; Hansen, 2010; 2012; Groth & Winther, 2013). The conclusions of these studies are that outsourcing is one significant factor where especially mass producing firms outsource production while retaining test facilities and R&D activities at home. Another important factor is that in particular firms specialised in product customisation increasingly invest in new capital goods. Thus production is increasingly automated resulting in reduced labour input. Both factors lead to a reduced demand for low skilled labour while the complexity of the production processes and the production systems increase the demand for highly skilled labour.

### **The geography of human capital in manufacturing**

The previous section showed an increasing share of highly skilled labour in manufacturing industries during the long term period of growth in Denmark. However, our study also shows major geographical differences in the share of highly skilled labour both at local and regional level. Figure 3 shows the LQ of highly skilled labour within manufacturing in Danish municipalities in 1993 and 2006 according to R&D intensity. At a general level, the maps for all four technology categories show that the LQ of highly skilled labour is below average in the majority of municipalities in Jut-

land, Funen and Lolland-Falster. Few municipalities have average or above average LQs. The high LQs are in general found in the built-up areas of Copenhagen and particularly in the municipalities along the Øresund coast to the north of the capital. Noteworthy is it that Aarhus municipality, home to the second most populous city in Denmark, only has a high LQ within low-tech manufacturing and that the third largest city Odense shows very low LQs in all four categories. Consequently, Greater Copenhagen stands out as the only region with a considerable concentration of highly skilled labour within all types of manufacturing industries. In fact, besides from Aarhus and rural municipalities with less than 20 highly skilled employees within manufacturing, all municipalities with an LQ of 2.25 or above in at least one of the four R&D categories are predominantly urban municipalities located in Greater Copenhagen (Hansen *et al.*, 2012).

**Figure 3. LQ of highly skilled labour according to manufacturing R&D intensity**



Source: Statistics Denmark & own calculations

There are, however, some differences between the four R&D categories with regard to how concentrated highly skilled labour is. Highly skilled labour in low-tech manufacturing is exceedingly concentrated in the built-up area of Greater Copenhagen and the concentration intensifies between 1993 and 2006. Conversely, the number of rural municipalities in Jutland and Funen with high concentrations of highly skilled labour in low-tech manufacturing has declined. Within medium low-tech the patterns of concentrations of highly skilled labour remains almost identical between 1993 and 2006 although the LQ in a number of municipalities in rural Zealand decreases. Medium high-tech manufacturing reveals a strong urban concentration pattern in Greater Copenhagen. This is a pattern that is strengthened between 1993 and 2006. By 2006 very few municipalities outside Greater Copenhagen exhibit LQs around or above the national mean. Finally, in the high-tech industries, highly skilled labour is also concentrated in the Greater Copenhagen area but the concentration does not seem to be intensifying to the same extent as in the low-tech industries. There are a few municipalities with high LQs outside Greater Copenhagen; however, most rural municipalities have LQs close to zero.

It is worth stressing that growth in highly skilled labour is closely correlated to overall employment growth – both in terms of manufacturing and total employment (see table 4). While this is in itself not surprising, it should be noticed that the correlation coefficient between employment and highly skilled labour growth in manufacturing (0.715) is considerably higher than the corresponding coefficient for the economy as a whole (0.603). Thus, although the question of causality still remains, the presence of highly skilled labour and overall growth appear to be particularly strongly related within the manufacturing industries.

**Table 4. Correlation coefficients, municipality scale (n = 270)**

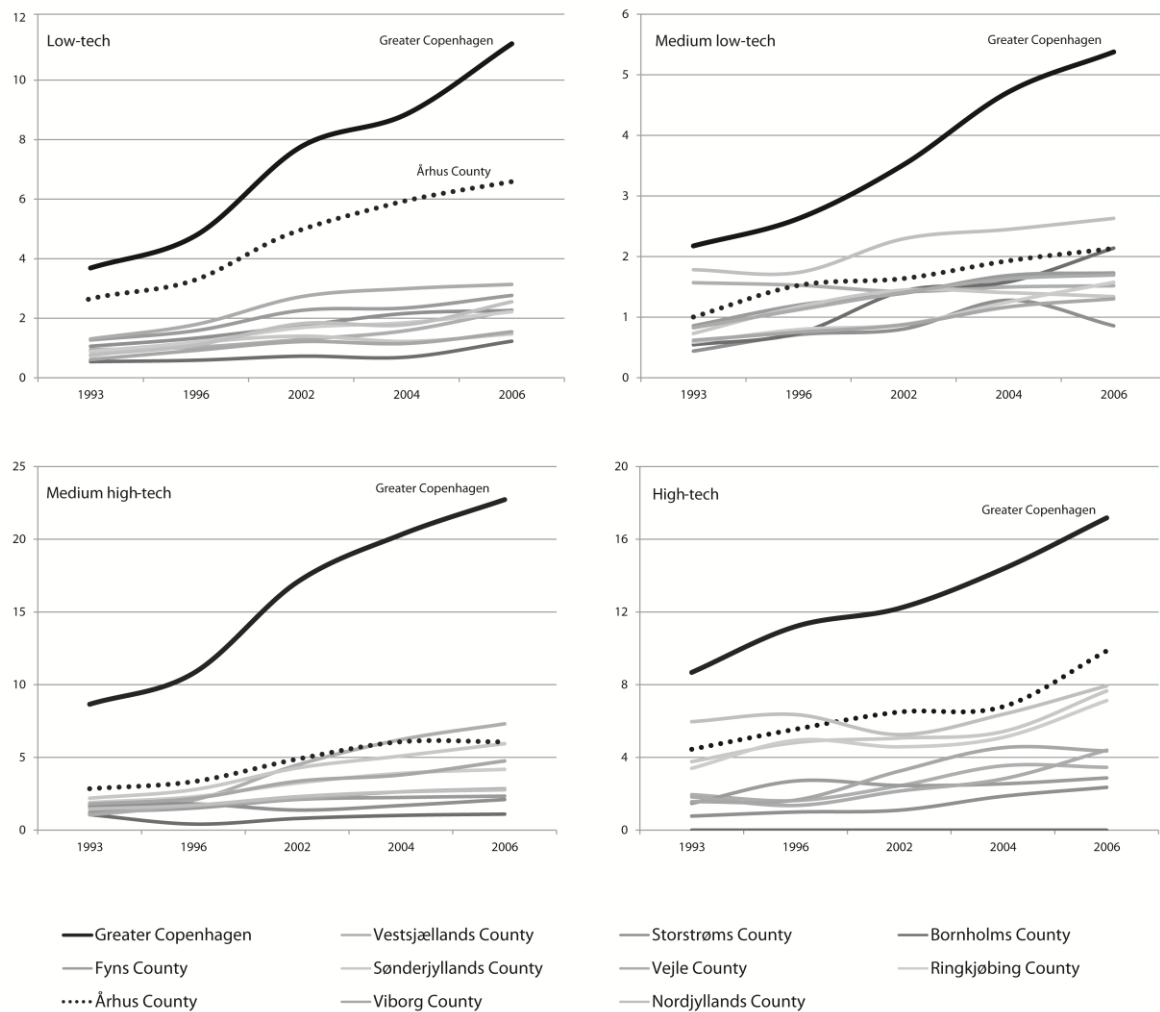
	Mean	S.D.	1	2	3
<b>1. Total employment growth, 93-06</b>	4.5	12.2			
<b>2. Manufacturing employment growth, 93-06</b>	-10.6	36.3	0.525		
<b>3. Total highly skilled labour growth, 93-06</b>	70.8	53.7	0.603	0.514	
<b>4. Manufacturing highly skilled labour growth, 93-06</b>	174.8	448.6	0.402	0.715	0.640

*All correlations significant at  $p < 0.001$*   
*Source: Statistics Denmark & own calculations*

To sum up, the maps in figure 3 to a large extent show an inverted image of the one presented in figure 2. Even though manufacturing employment is increasingly concentrated in the rural parts of Jutland, employment of highly skilled labour in both low-tech and high-tech industries remains very much an urban phenomenon with increasing concentrations in and around Copenhagen.

Even though the analysis of municipalities points towards an increasing spatial divide between the large urban regions and the rest of the country – especially the industrialised rural regions – concerning employment of highly skilled labour, the picture at the municipality level is not fully consistent with the reality, as figure 3 shows that some municipalities in rural regions exhibit high LQs of highly skilled labour. This is primarily explained by the fact that LQ only acts as a measure of concentration, and a limited number of highly skilled workers in a small workforce can therefore result in a high LQ. If municipalities are aggregated to county level the urban/rural divide becomes even clearer, as shown in figure 4.

**Figure 4. Share of highly skilled labour (%) according to manufacturing R&D intensity 1993-2006**



*Source: Statistics Denmark & own calculations*

Figure 4 provides an overview of the share of highly skilled labour within manufacturing in Danish counties from 1993 to 2006. The main result is that Greater Copenhagen exhibits the highest share of highly skilled labour throughout the time period examined and also shows much higher growth rates in all levels of technology compared to the other counties. The only other county that stands out in terms of growth in the share of highly skilled labour is Aarhus and it only does so in low-tech industries. There is a modest increase in the share of highly skilled labour in the other counties,

however, it does not compare to the development in Greater Copenhagen. Thus, the analysis at the county level confirms the picture from the analysis at the municipality scale: there is a clear urban/rural divide in the localisation of highly skilled labour within all types of manufacturing industries favouring municipalities in and around Copenhagen and this divide has been deepening over time.

## **CONCLUSION**

An essential feature associated with the rise of the knowledge economy has been the increasing focus on the importance of human capital as a precondition for economic growth. Furthermore, in light of the escalating economic globalisation policymakers and academics also emphasise the crucial character of the high-tech sector which is thought to be more resistant to global price competition. These two arguments come together in the idea that human capital is particularly important for the economic development of high-tech industries.

The purpose of this paper has been to examine empirically the validity of this argument by analysing the use of human capital over time in low-tech industries. Analysing the changing share of highly skilled labour in Danish manufacturing industries over the period 1993 to 2006 provides little evidence of a particularly close relationship between human capital and high-tech industries. The analysis shows that while there is a net-increase in the number of highly skilled workers within all types of manufacturing industries, the share of highly skilled labour is growing the most in low-tech industries. In fact, the share of highly skilled labour is now considerably higher in low-tech industries than in the more R&D intensive medium low-tech industries. Thus, human capital appears to be of crucial importance in low-tech industries as well.



Turning to the geographical analysis, the results show that whereas manufacturing employment is increasingly located in the rural parts of Denmark, the highly skilled labour within manufacturing is predominantly concentrated in the urban regions. Moreover, the data reveals that these geographical differences are intensifying over time. The share of highly skilled labour in the built-up area of Greater Copenhagen increases significantly throughout the period, especially within the less R&D intensive industries. This presents a classic spatial division of labour with headquarter activities located in the city region and branch plants located in more peripheral regions (Massey 1984; Christofferson & Clark 2007). However, the Danish manufacturing sector consists mainly of independent small and medium sized firms, thus, the geographical pattern of skills in manufacturing is also likely to result from differences in access to highly skilled labour pools.

These conclusions stress that human capital appears to be equally important for economic development in low-tech industries. Further, the results indicate that the urban/rural divide plays the primary role in explaining the geography of human capital rather than the localisation of high-tech industries. Hence, it seems that agglomeration economies are strongly underpinning the knowledge economy. These findings have important policy implications. Firstly, while other studies have stressed the significant economic importance of non-R&D intensive industries in developed countries (Kaloudis *et al.*, 2005; Hansen & Winther, 2011b), this study further emphasises that low-tech industries are not merely waiting to be outcompeted by firms from low-cost countries. Rather, they are restructuring and significantly increasing the proportion of highly skilled labour to improve their competitiveness and ability to innovate. It therefore seems misguided to target policies aimed at attraction and retention of highly skilled labour specifically towards high-tech industries.

Secondly, the conclusions raise questions concerning regional policy. It is difficult to imagine a reversal or even a pause in the trend towards a deepening divide in the skill levels of employees in urban and rural locations. Thus, a major challenge for policymakers is to ensure a continuing viabil-

ity of the manufacturing activity in peripheral locations, taking into consideration the relative decline in educational attainment relative to urban regions. The importance of this challenge is underlined by the increasing economic significance of manufacturing in these areas. While the answer may partly lie in the strengthening of inter- and intra-firm linkages to partners with a large share of highly skilled labour (often in urban locations), this topic constitutes an important avenue for future research.

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## APPENDIX A

**Table A1. Paired sample t-tests for the growth in the share of highly skilled labour 1993-2006, municipality level**

	t	df	P	Mean (1)	Mean (2)
(1) Low-tech – (2) Medium low-tech	3.79	138	0.000	1.77	0.89
(1) Low-tech – (2) Medium high-tech	2.38	157	0.019	1.90	1.28
(1) Low-tech – (2) High-tech	2.07	72	0.042	2.17	1.33
(1) Medium low-tech – (2) Medium high-tech	-1.33	124	0.185	0.93	1.32
(1) Medium low-tech – (2) High-tech	-0.37	60	0.713	1.27	1.42
(1) Medium high-tech – (2) High-tech	0.51	66	0.611	1.45	1.28
<i>Mean values vary, as observations are only included if growth rates can be calculated for both types of industries in the pair</i>					

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