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Innovation, regional development and relations between high- and low-tech industries

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Abstract

The current European policy agenda strongly accentuates the importance of research and development (R&D) as a driver of economic growth. The basic assumption is that high European wage levels make it unlikely that less research intensive parts of the economy can withstand competition from low-wage countries with increasingly skilled labour forces. Thus, the inferior growth of the EU in the 1990s compared to the US has been explained by the latter's higher rate of R&D investments. The paper challenges this rather simplistic view of innovation and examines the regional consequences of such policies. EU growth has caught up with the US during recent years and low-tech industries continue to have considerable economic importance in Europe in terms of jobs and value added especially outside the main growth regions, but also in the major urban regions. Empirical evidence from Denmark and the UK provided in the paper suggests that low- and high-tech industries are closely interconnected as low-tech firms play important roles both as partners in the innovation processes of high-tech firms' and as buyers of high-tech products. Therefore, EU industrial policy is inexpedient as it overlooks the continuing significance of low-tech industries. Furthermore, the rather uniform focus on R&D is associated with a strong emphasis on large city-regions where research intensive industries are concentrated, and thus, increasing regional inequality in Europe is being produced.

Keywords: Low-tech industries; Innovation; Firm linkages; Regional inequality; EU industrial policy

Introduction

The paper examines the importance of innovation in low-tech industries as a driver of economic growth and contrasts this with the strong emphasis on "science-push" in European policymaking. It is argued that the failure to recognise the interdependency of high- and low-tech industries will restrain economic development including perspectives for less favoured regions. Furthermore, a continuing focus by European governments and the EU on the importance of research and development (R&D) for economic growth will hence increase inter-regional inequality due to the inability of peripheral regions to compete for especially high-tech industries that tend to favour city-regions. Thus, there is a strong bias towards city-regions, where research intensive firms are concentrated, in current industrial policymaking.

The relatively low amount of R&D investments in Europe relative to the US has frequently been emphasised as a main explanation for the latter's higher GDP growth and productivity during the 1990s (e.g. Sapir et al., 2003; European Commission, 2004). The underlying assumption is that the high European wage levels make it unlikely that the less research intensive parts of the economy can withstand competition from low-wage countries with increasingly skilled labour forces. Consequently, continuous investments in R&D leading to radical innovations are prioritised to achieve long-term economic prosperity. Associated with this is a focus on high-tech industries defined by their R&D intensity and subsequently the regions, often large city-regions, where these industries are concentrated. Thus, industries with lower R&D intensity are receiving decreasing attention by policymakers and this will in the end also have significant effects on regions focused mainly on low-tech industries.

The aim of the paper is to challenge this close relationship between, on the one, hand R&D and high-tech industries and, on the other hand, (regional) economic growth. Previous work has contested the background for the so-called productivity gap between the US and EU and concludes that explanations for differences in growth are based on a number of factors (Dunford, 2005a; 2005b). Additionally, growth rates in Europe have been higher than in the US in recent years which further erodes the argument focusing solely on the differences in R&D investments. Also it is hard to find evidence for the expected superior performance of European high-tech industries during the last few decades compared to industries with lower R&D intensity. This conclusion will be documented below.

The reasons for the continuing competitiveness of European low-tech industries have recently attracted attention from some scholars (Bender and Laestadius, 2005; Hirsch-Kreinsen et al., 2006; Radauer and Streicher, 2007; Kirner et al., 2009; Hansen, 2010). Prominence in these studies is given to innovation strategies focusing on step-by-step developments of products, refinement and specialisation of production processes and customisation of products (Hirsch-Kreinsen, 2008). The significance of these innovation processes have been analysed elsewhere and the empirical focus of this paper is instead on the interconnectedness between low- and high-tech industries. It is often forgotten that low-tech firms fulfil important roles both as partners in high-tech firms' innovation processes and as buyers of high-tech products. These aspects are described on the basis of 31 interviews with key actors from British and Danish low-tech firms and industrial organisations.

The main argument presented on the basis of this analysis is that the development paths of high-and low-tech industries are highly interconnected and the importance of R&D

for European economic development should not be overstated. It is a very simplistic view to consider increasing R&D funding as the key to future economic prosperity in Europe, when industrial development depends on multiple relations within and across industries in various stages of the production process. Yet, there is a tendency among policymakers to exaggerate the crucial character of R&D and high-tech industries thereby overlooking the continuing weight of low-tech industries as well as the interdependence of low- and high-tech industries. There are no reasons to regard policies stimulating incremental innovation and adaptation of technologies in low-tech industries and policies facilitating cooperation between high- and low-tech firms as less important for economic growth than policies aiming at stimulating spending on R&D.

Regions, knowledge and innovation

A strong consequence of globalisation in the form of for instance trade liberalisation and improved infrastructure is pressure on the competitiveness of firms in the industrialised countries. Further, the increasing global diffusion of knowledge leads to higher productivity in low-wage countries, and a continuous creation of knowledge is therefore necessary if the industrialised countries are to maintain their competitive advantage (Maskell and Malmberg, 1999). Thus, recently there has been a significant focus on the knowledge economy and high-tech industries and especially radical innovations and the analytical knowledge base in studies of regional development, national innovation systems and the EU's competitiveness. The knowledge economy has emphasized the importance of innovation in generating competitive firms, nation states, cities and regions. The spatial consequences of this focus is a marked concentration of interest on the resurgence of the large city-regions (Scott, 2008; Hansen and Winther, 2010), learning regions (Morgan, 1997) and high-tech regions (Asheim and Coenen, 2006). The competitiveness of firms and hence cities and regions, it is argued, increasingly depends on their ability to innovate by improving their productivity through process innovation, including new forms of organisation, product quality or by producing new products (David and Foray, 2002) which is very similar to the definition made by Schumpeter (1943). However, innovation is more complex than just a focus on R&D-based innovations and high-tech learning. According to Amin and Cohendet (2004), a critical aspect of the innovation process is knowledge and the understanding of knowledge production as an interactive, relational learning process because knowledge contains an innovative potential, but knowledge does not become innovation before it is introduced on the market (Edquist, 1997). Whether this happens, depends on the cost related to implementing this knowledge and the likely gains on the market (Rigby, 2003).

Thus, one way to distinguish between innovations is to consider their relation to current technology. A constant improvement of a product or a production process is considered as an incremental innovation, as it is not fundamentally different from well-known technologies. A radical innovation is, in contrast to incremental change, completely different from the current products or processes available on the market, and a number of related radical innovations can together constitute a technological revolution, which has great impact on society as a whole (Fagerberg, 2005).

Whether firms in an industry primarily create incremental or radical innovations depends fundamentally on the characteristics of the industry including the skills of the workforce – this can overall be termed the industrial knowledge base (Asheim and Gertler, 2005; Asheim and Coenen, 2006) and is related to the frameworks of national and regional innovation systems (Lundvall, 1992; Cooke, 2001), hence including the institutional framework of the innovation process. Asheim and Gertler (2005) distinguish between two main industrial knowledge bases. An analytical knowledge base is characterised by an emphasis on knowledge creation through the use of scientific methods and modelling. The links between research institutions, universities and firms are consequently of great importance for this kind of knowledge production. The use of codified knowledge is extensive, and the results are most often also codified and documented through patents and publications – but even highly codified knowledge requires tacit knowledge to implement (Nonaka and Takeuchi, 1995; Amin and Cohendet, 2004). Overall, these characteristics imply that most innovations based on an analytical knowledge base are mainly radical.

The synthetic knowledge base utilises existing knowledge rather than creating completely new knowledge and hence are in contrast to the analytical knowledge base. The availability of workers with practical and engineering skills is regarded as essential and tacit knowledge, learning by doing and learning by using therefore has a greater importance than the scientific based codified knowledge. The objective of the innovation process is often to solve specific problems for a customer, and the relations between agents/firms in the commodity chain are thus of significant importance for producing new innovations. A knowledge base with these attributes will therefore primarily produce incremental innovations.

Obviously, many firms combine the two ideal types of knowledge base. In fact, Jensen et al. (2007) find that such firms tend to be more innovative than firms relying on only one of the two knowledge bases. Jensen et al. (2007) confirm 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 frequently essential for scientists working in R&D departments of high-tech firms in the process of designing research projects and interpreting results. Similarly, scientific knowledge is often part of the solution for firms which otherwise emphasise learning-by-doing and learning-by-using. Accordingly, the STI and DUI modes are not entirely dependent on the analytical and synthetic knowledge base, respectively, but include elements from both (Asheim, 2009).

The radical innovations that derive from an analytical knowledge base are given prominence over the incremental innovations in the work of Schumpeter (Fagerberg, 2005). Schumpeter (1943; p. 117) notes that “Technological progress is increasingly becoming the business of teams of trained specialists”, while Vannevar Bush describes innovation as a set of strict calculations, where scientific research constitutes the first stage in the development of an innovation, followed by product development, production and finally marketing (Bush, 1945). However, several important criticisms of this model, which has subsequently been termed the linear model of innovation, have been raised (Nelson and Winter, 1982; Dosi et al., 1988; Lundvall, 1992; Nonaka et al., 1996; Edquist, 1997; Amin and Cohendet, 2004). Firstly, few innovations actually happen in this way. Innovations are often driven by demand or result from new ways of combining known knowledge. The importance of science based knowledge production is hence exaggerated and the learning processes are highly complex crossing various communities (Amin and Cohendet, 2004). Secondly, the interactions and feedbacks from customers and suppliers are important in innovation processes, but the linear model ignores this (Henry et al., 1995). This of course led to the development of the chain-linked model of innovation by (Kline and Rosenberg, 1986), which describes innovation processes as complex and disorderly. In line with this, we will show in the empirical part of this paper that a key flaw of the linear model of innovation is the failure to consider the inter-relations between high- and low-tech firms for innovation processes.

Measuring innovation

The linear model of innovation was very influential in the decades following the Second World War (Cooke and Morgan, 1998). The term itself was not introduced before the late 1960s (Edgerton, 2004), but the idea of a linear innovation process developed through the 20th century. Statistical offices played a key role in the crystallisation of the model into a social fact (Godin, 2006) and collection of data on basic research. Applied research and development continues to be an important reason for the persistant significance of the model in the eyes of policymakers (Godin, 2006), including those in the EU as well, as we will see below.

An important way in which the science-based view of innovation influences policy-making is through industrial classifications based on this model of innovation. The most influential classification system is the one used by the OECD and Eurostat, which is based on the R&D intensity of different industries. Outcomes of R&D are characterised by significant elements of novelty and scientific or technological progress (OECD, 2002), and the R&D intensity depends on the ratio of R&D expenditures to the output value of the sector. Four categories are used (Smith, 2005):

1. High-tech industries: R&D intensity above 5%.
2. Medium-high-tech industries: R&D intensity between 3% and 5%.
3. Medium-low-tech industries: R&D intensity between 1% and 3%.
4. Low-tech industries: R&D intensity below 1%.

Table 1 shows the resulting OECD classification of manufacturing industries. A newer version following the NACE rev. 2 has been introduced (Eurostat, 2009), but the latest available data on industries' value added is from 2006 and thus follows NACE rev. 1.1.

Table 1. Manufacturing industries classified according to R&D intensity – NACE rev. 1.1 codes in brackets

High-tech	Medium-high-tech
Pharmaceuticals (24.4)	Chemicals - excl. pharmaceuticals (24 excl. 24.4)
Computers, office machinery (30)	Non-electrical machinery (29)
Electronics-communications (32)	Electrical machinery (31)
Scientific instruments (33)	Motor vehicles (34)
Aerospace (35.3)	Other transport equipment (35.2+35.4+35.5)
Medium-low-tech	**Low-tech**
Coke, refined petroleum products and nuclear fuel (23)	Wood, pulp, paper products, printing and publishing (20-22)
Rubber and plastic products (25)	Food, beverages and tobacco (15-16)
Non metallic mineral products (26)	Textile and clothing (17-19)
Basic metals (27)	Other manufacturing and recycling (36-37)
Fabricated metal products (28)	
Shipbuilding (35.1)	

Source: OECD (2004)

Lately, organisations such as the OECD have started to put more emphasis of issues such as capital input from knowledge intensive industries and human capital (OECD, 2007) and highlight intangible investments rather than merely R&D investments (OECD, 2009). However, the overall focus on R&D intensity persists among public policymakers. The simplicity of this taxonomy makes it very attractive in a policy context, as it is very precise and easy to measure (Jacobson and Heanue, 2005; Godin, 2006) contrary to the more detailed alternatives, which have been developed over the years. Pavitt (1984) presents a taxonomy that overcomes this limited view of innovation, as it includes innovation through the employment of skilled employees, learning by doing and learning by using. Firms can therefore be considered as high-tech even though the actual R&D intensity is relatively low. Another alternative is developed by Bar-El and Felsenstein (1989) where the technological intensity of an industry depends on the percentage of academic and skilled labour, the technological intensity of capital (investments in sophisticated machinery or processes), and the technological intensity of the product (R&D intensity). Finally, Laestadius et al. (2005) present an attempt to combine the work of previous scholars. As well as arguing for the inclusion of similar measures as Pavitt (1984) and Bar-El and Felsenstein (1989), they also stress the importance of a number of other indicators. Measures reflecting the ability to design solutions through synthesising different fields of knowledge, and indicators measuring the organising capacity, are seen as necessary to describe the full innovativeness of firms and sectors. Further, they state that describing the innovativeness of industries through one innovation indicator is a reductionism. A complex issue like innovation needs different indicators, which cannot be compiled in one.

European innovation policy

These alternative and more detailed taxonomies have, however, had limited impact, and innovation continues to be closely related to the taxonomy based on R&D intensity amongst policy makers (Jacobson and Heanue, 2005). Sectors with lower R&D intensity are regarded as being less important for long term economic growth and especially manufacturing is given a low priority, both by the European Union (Hirsch-Kreinsen, 2005) and by national governments e.g. in the United Kingdom (Turok, 2004) and Denmark (Hansen, 2010). Increasing investment in R&D has been a key policy priority since the Lisbon Strategy established the EU target for R&D spending at 3 % of GDP. The influential Sapir Report finds that EU economic growth has been inferior compared to the US and that low levels of investment in R&D is an important reason for this. A central recommendation of the report is that the EU should focus on reducing inter-national economic differences and leave the responsibility for intra-national inequality to the individual member states. Associated with this alteration of the hitherto coherence of policy is an emphasis on growing regions and investment in R&D (Sapir et al., 2003) which does not take the diversity of European regions into account (Birch et al., 2010).

A number of other EU reports have dealt with the connection between growth and R&D investment. The annual European Competitiveness Reports highlight the importance of high-tech industries and R&D investment for future economic growth, but their view on competitiveness is quite broad compared to that found in other reports published by the European Commission where it is evident that a knowledge-based economy is considered to be very closely linked to the significance of R&D. Examples include the innovation scoreboards (Jensen et al., 2007; Hollanders et al., 2009), the so-called Aho Report prepared after the revision of the Lisbon Strategy (European Commission, 2006b), and the process of producing indicators for monitoring the development of the European Research Area (European Commission, 2008).[1] In some instances, it appears as

[1] A notable exception from this plethora of high-tech focused reports is the publication Constructing Regional Advantage prepared by a group of 11 European scholars (European Commission, 2006a). The report takes a balanced and inclusive view on innovation policy but it appears as if it has had little influence on the overall innovation policy promoted by the EU.

if increasing R&D investment is a goal in itself rather than a means to achieve stronger economic growth:

> "Given the weight of high-tech sectors in the overall level of business R&D intensity, a change should include the sectoral composition of the business sector, a move towards a higher share of high-tech companies and research-driven clusters."
>
> (European Commission, 2008; p. 11)

Thus, it is stated that it is a policy challenge to "change the balance of the industrial structure in favour of these research-intensive sectors" (ibid.; p. 16), implying that development of low-tech industries is to be given a low priority. An important argument for this emphasis on high-tech industries and R&D policies has been the superior economic performance of the US which has traditionally invested a higher percentage of GDP in R&D (European Commission, 2004). The illuminative work of Boltho (2003), Gordon (2004) and Dunford (2005a; 2005b) has, however, questioned the background for the apparent inferior economic performance of EU compared to that of the US.

Firstly, EU productivity growth outperformed the US from 1989 to 2002, but GDP grew slower as the average number of working hours decreased in Europe. This development is largely voluntary – it is a trade-off in favour of leisure time which maximises the welfare of people – and a lower GDP growth should therefore not necessarily be a concern.

Secondly, a number of factors increase GDP in the US without improving welfare, such as demand for heating and air conditioning due to climate conditions, the need for car journeys owing to a lack of public transport, security measures as a result of high crime rates and litigation due to a relatively low degree of inter-personal trust in the US society.

Finally, a number factors have contributed to increase and decrease the growth in the US and EU respectively, including the escalating indebtedness of US households and the US economy, the restrictive EU macroeconomic measures such as the monetary policy of the European Central Bank and the EU's stability and growth pact, as well as the large costs in the 1990s associated with the German reunification.

Thus, there are many issues which need to be taken into consideration when the economic development of EU and the US is compared. Moreover, EU GDP per capita growth rates have caught up with the US in recent years. The US achieved the largest GDP per capita growth rates through most of the 1990s but the picture changed after the millennium and the burst of the IT bubble. Figure 1 reveals that growth has been almost similar, looking at the period as a whole. Taking 1989 as a baseline (index = 100), EU per capita GDP growth reached an index value of 137.4 in 2008, slightly surpassed by the US with a figure of 137.5. Thus, taken as a whole, there seems to be little relevance in arguing for a greater emphasis on R&D in European policymaking on the basis of the performance of the US economy. The subsequent section will examine whether the underlying assumption that technology intensive industries have a superior competitiveness compared to low- and medium-low-tech (LMT) industries can be supported empirically.

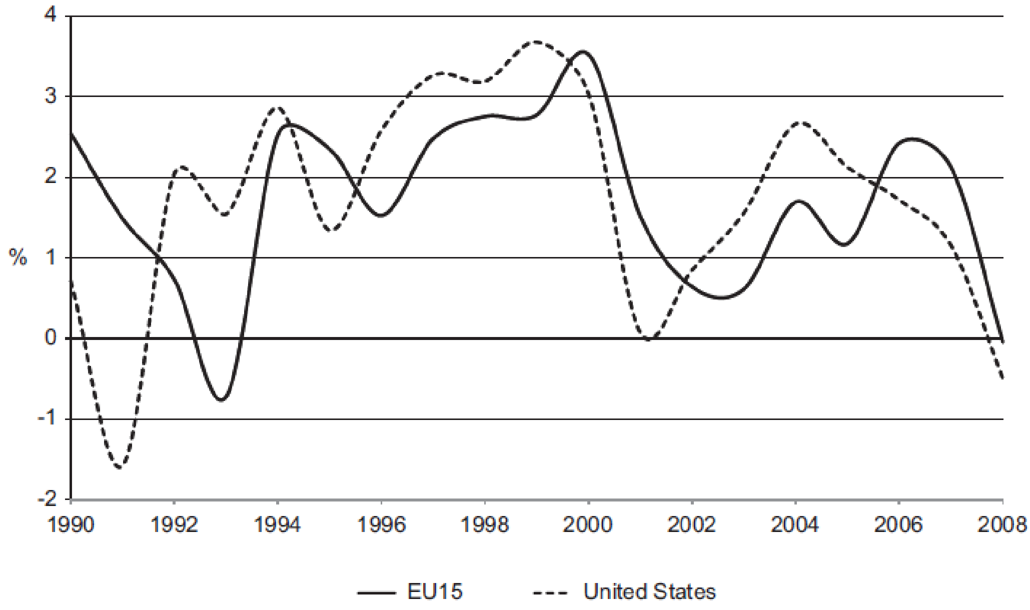

Figure 1. GDP per capita, year-on-year growth rates: EU15 and USA, 1990–2008 (constant prices and PPP)
Source: Own elaboration on the basis of figures from OECD's STAN database.

The economic importance of low- and medium-low tech industries in Europe

The importance of LMT industries for the industrialised economies is extensive. Kaloudis et al. (2005) show that low-tech industries remained of key importance in a sample of 11 OECD countries both in terms of employment and value added over the period 1980-1999. A similar conclusion can be reached studying industrial development in 12 European OECD countries – Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden and United Kingdom – from 1995 to 2006.

Figures 2 shows the development in share of gross value added according to R&D intensity. The low-tech sector's share falls by a little less than 4 % from 1995 to 2006, while the two medium tech sectors experience minor increases of approximately 1 %.

Interestingly, the share of the high-tech sector has been very stable over the years: the share initially increased from 10.2 % in 1995 to 12.3 % in 2000, but has since then only varied between 11.8 % and 12.3 %. Furthermore, the total value added of the high-tech sector is significantly lower than the value added of the three other sectors.

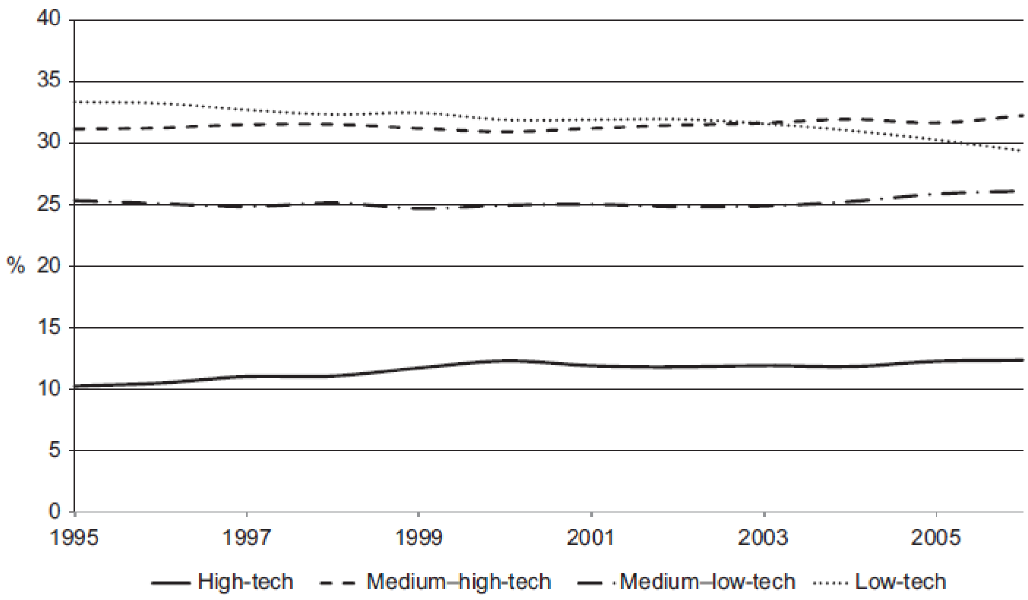

Figure 2. Shares of manufacturing value added for 12 European countries, 1995–2006 (percent)
Source: Own elaboration on the basis of figures from OECD's STAN database.

The overall picture is thus one of stability: the LMT industries continue to play a key role for the economic development of European countries eventhough their share of value added has decreased over the period. The same can be said in terms of the different sectors' shares of manufacturing employment (Figure 3). Employment in the low-tech sector in ten European countries – the Netherlands and the United Kingdom are excluded due to data availability – continues to be the greatest by far, even though it has decreased by approximately 3 % between 1995 and 2006. Conversely, the shares of the medium-low-tech and the medium-high-tech sectors increased by respectively 1.7 % and 1.4 %. Notably, the high-tech sector's share of employment remained completely stable over the period, fluctuating only between 8.1 % and 8.4 %.

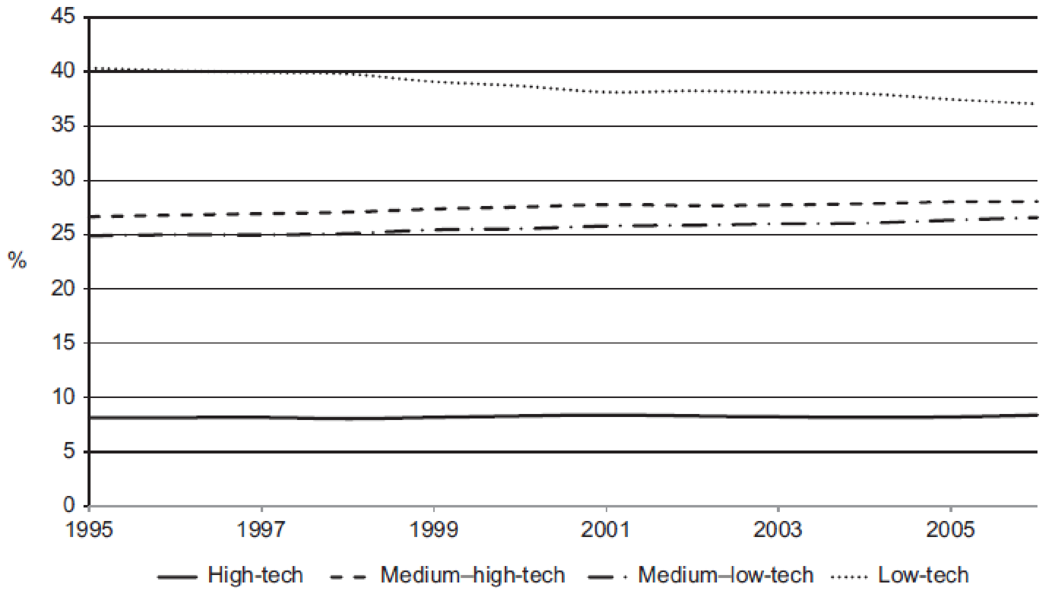

Figure 3. Shares of manufacturing employment for 10 European countries, 1995–2006 (percent)
Source: Own elaboration on the basis of figures from OECD's STAN database.

A further interesting analysis is to compare the development of labour productivity (value added per employee) for the four different sectors. Unfortunately, detailed statistics on the number of hours worked according to the industries' R&D intensity are not available, and the size of employment is therefore used as an input variable eventhough there might be inter-sectoral differences. This is, however, not considered a major problem, as the development over time is of the main interest.

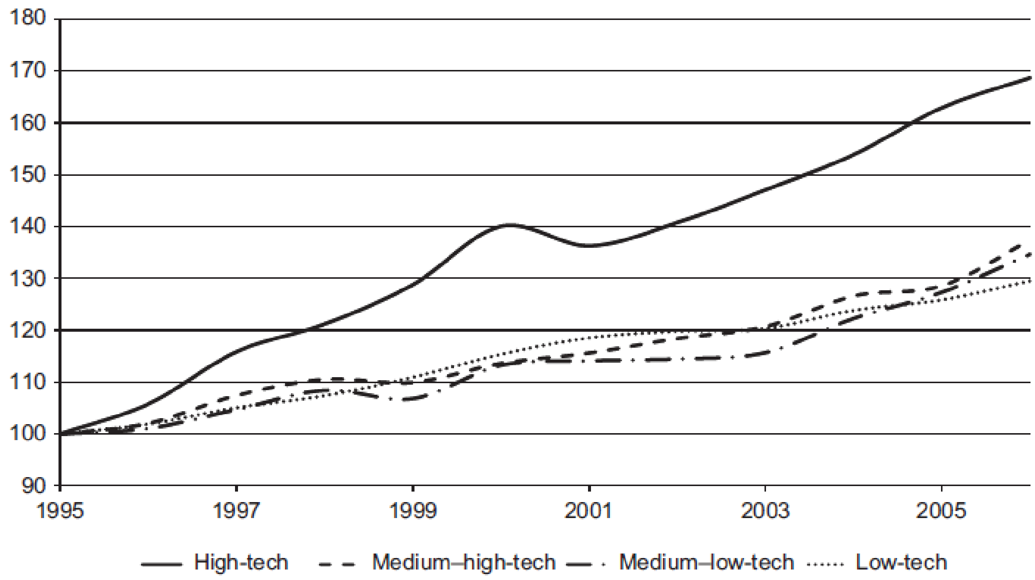

Figure 4. Value added per employee for 10 European countries, 1995–2006 (1995 = index 100)
Source: Own elaboration on the basis of figures from OECD's STAN database.

All four sectors have seen increasing levels of labour productivity but taking 1995 as the point of reference, it is seen from Figure 4 that the index value of the high-tech sector has increased the most. It is furthermore interesting to see that the development of the three remaining sectors have been very similar over the period. However, including only the years since the millennium provides a different picture (see Figure 5 – the scale of the y-axis is similar to Figure 4 to ease comparison): since 2000, few differences can be observed between all four sectors, eventhough the growth of labour productivity in the low-tech sector has been somewhat below those of the other three sectors in 2005 and 2006. The most important observation is nevertheless that the high-tech sector's superior growth rates in labour productivity from the second part of the 1990s have not continued – the high-tech growth rate is now comparable to the remaining sectors.

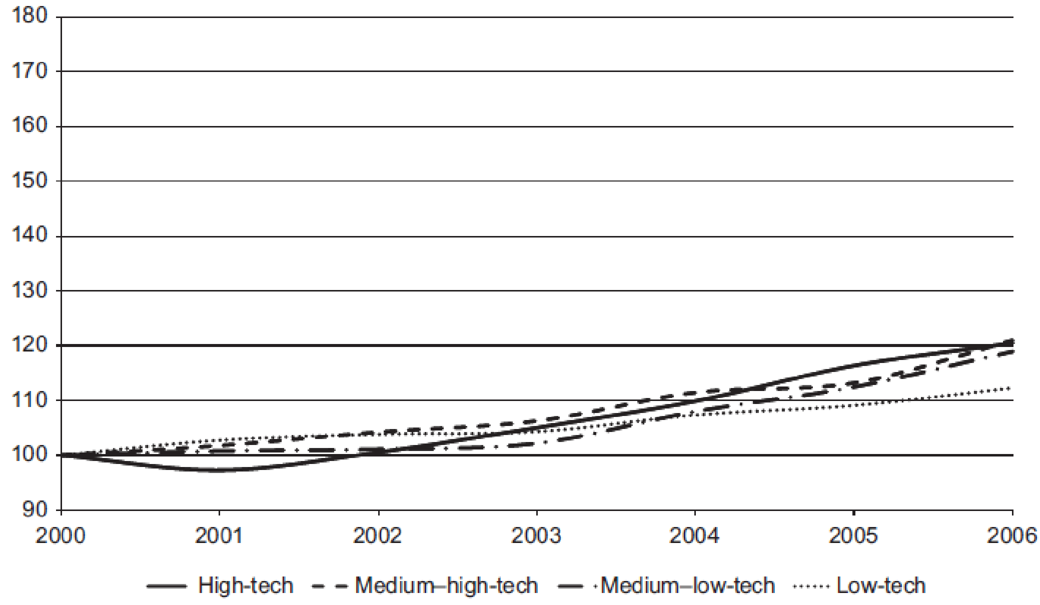

Figure 5. Value added per employee for 10 European countries, 2000–6 (2000 = index 100)
Source: Own elaboration on the basis of figures from OECD's STAN database.

Overall, the data show that eventhough the growth rates of R&D intensive industries have been high from 1995 to 2006 in terms of value added and labour productivity, no radical change has taken place in the composition of the European manufacturing sector: the total value added of LMT industries is significant and it continues to increase. Furthermore, these industries maintain a crucial role in terms of employment, as they make up more than 63 % of all manufacturing jobs. Finally, the growth of LMT labour productivity has not developed significantly differently from high-tech industries in the period after the millennium. In general, there seems to be little empirical evidence for maintaining an excessive policy focus on high-tech industries and thereby neglecting LMT industries.

The value added of LMT industries

The puzzle of how LMT firms remain competitive in high-wage countries has in recent years been studied on a number of occasions including a cross-European study (Bender and Laestadius, 2005; Hirsch-Kreinsen et al., 2006), case studies in Austria (Radauer and Streicher, 2007), Taiwan (Chen, 2009) and Denmark (Hansen, 2010) as well as analyses of LMT sectors in Germany (Kirner et al., 2009) and Spain (Santamaria et al., 2009). The studies show how LMT firms utilise their mainly synthetic knowledge base in a number of ways. The most widespread innovation strategies are described by (Hirsch-Kreinsen, 2008), as follows:

- Step-by-step is based on a continuous improvement of the product produced.
- Customer orientation combines existing knowledge in new ways in order to develop tailored products and solutions.
- Process specialisation focuses on improving the technical organisational process structures.

In addition to the value added created directly in LMT industries it is often forgotten that low-tech firms fulfil important roles both as partners in the innovation processes of high-tech firms' and as buyers of high-tech products (a notable exception being Robertson and Patel (2005)).[2] Thus, the interconnectedness of low- and high-tech industries is also of significant importance for the economic development in high-tech industries.

[2] A third way in which high- and low-tech industries are connected is through the gradual increase in research intensity of some – previously – low-tech industries, e.g. the Norwegian solar cell industry (Hanson, 2008). Thanks to Arne Isaksen for drawing our attention to this.

The following section explores these issues drawing on 31 interviews with key actors from British and Danish firms (25 interviews) and industrial organisations (6 interviews) from the fabricated metal and plastic industries. The two industries are chosen, as they are among the most important non-research intensive industries in Europe, both in terms of employment and value added. Interviews took place in two countries in order to reduce the risk of capturing nation-specific trends, but no striking differences have been found between the Danish and British firms. Firms of different sizes have been interviewed, but we do not claim any representativity – the aim of the analysis is to gain an insight into innovation dynamics and the interactions between high- and low-tech firms, not to generalise about innovation characteristics in the fabricated metal and plastic industries. Still, key characteristics of the firms and comparison to the overall populations are given in table 2. Unfortunately, not all information is available for both Danish and UK firms, but the interviewed firms are generally larger than the wider populations of fabricated metal and plastic firms in the two countries in terms of employment and turnover (UK figures only). Further, the interviewed Danish firms are more likely to export goods as well as to serve end users rather than producing intermediate outputs.

The Danish firms are located in the region around the fourth largest city in Denmark, Aalborg, while the British firms are from the West Midlands and Yorkshire, in the area between Birmingham and Leeds. The firms are in this way comparable, as they are neither located in large cities nor in the most peripheral parts of the two countries. We have selected the specific regions as we are primarily interested in the interactions of firms located in such areas and furthermore, we want to ensure that the industries are of considerable economic importance in the regions. The two areas fulfil both of these conditions.

Table 2. Characteristics of interviewed firms compared to the populations

DANISH FABRICATED METAL AND PLASTIC FIRMS			
	Interviewed firms	Population (case area)	Population (Denmark)
EMPLOYMENT SIZE DISTRIBUTION (2009)			
5-49 employees	69 %	79 %	85 %
50-249 employees	23 %	17 %	13 %
+ 249 employees	8 %	4 %	3 %
SHARE OF FIRMS EXPORTING (2009)			
Exporting firms	69 %	47 %	n/a
MAIN PRODUCT FOCUS (2009)			
For end users	31 %	28 %	n/a
For further processing	69 %	73 %	n/a
UK FABRICATED METAL AND PLASTIC FIRMS			
	Interviewed firms	Population (case area[1])	Population (UK)
EMPLOYMENT SIZE DISTRIBUTION (2010)			
5-49 employees	50 %	88 %	89 %
50-249 employees	33 %	10 %	10 %
+ 249 employees	17 %	2 %	1 %
TURNOVER SIZE DISTRIBUTION (2010)			
£50,000-£249,000	17 %	42 %	46 %
£250,000-£999,000	33 %	31 %	30 %
+ £1.000,000	50 %	27 %	24 %

[1] West Midlands and Yorkshire and The Humber – thus the figures also includes the firms located in the urban areas which were not considered for the interviews

Sources: Own data collection, figures from KOB's database and ONS (2010)

Purchasers of radical innovations

Analyses of inter-industry technology flows were pioneered by Scherer (1982) who showed how LMT industries are important purchasers of technologies from industries with high R&D intensity. Sector studies in the construction industry (Arditi et al., 1997) and the plastics industry (Patrucco, 2005) have since confirmed the dense linkages with more research intensive industries. The technological interdependence amongst industries has increased over time as sourcing of technology becomes of greater importance (Robson et al., 1988). Use of advanced machinery has recently been identified as a central source of innovation for LMT firms (Santamaria et al., 2009; Heidenreich, 2009), and purchasing capital goods with inbuilt R&D is also of considerable importance to the innovation strategies of most of the firms interviewed in this study. One Vice President of a Danish fabricated metal firm explained how recently acquired computed numerically controlled (CNC) machines can be programmed to work through the night without monitoring, resulting in significant productivity improvements. A second example is given by a Department Manager who described how new industrial robots and close cooperation with suppliers have minimised the firm's expenses associated with welding.

Thus, the suppliers of these technologies are essential for the diffusion of scientific and engineering knowledge to LMT firms which they can apply in their own innovation processes (Storper, 1997). At the same time, the rate of return to technological innovations is positively correlated with their diffusion. Interestingly, there is a general awareness among the LMT firms that they are in a strong negotiating position vis-à-vis the suppliers of machinery and technological equipment. As one interview person phrased it:

> "Yes, access to their technology is important for us. But access to our funds is just as important for them."
>
> Head of Production, Danish fabricated metal firm

An industry representative expressed a similar viewpoint:

> "Our firms are tired of being labelled as non-innovative because they have a limited R&D budget. The amount of funds used on capital expenditure is equally important to get a full picture of innovativeness."
>
> Operations Director, British industrial organisation

Accordingly, the emerging picture is one of interdependency where firms indirectly benefit from R&D, but also indirectly pay for it. LMT firms constitute 64 % of total industry expenditure in Denmark (Statistics Denmark, 2009) and it is apparent from the interviews that they are aware of the significant economic influence that they exert.

Joint developments of radical innovations

Both Robertson and Patel (2005) and Mendonca (2009) find that LMT firms increasingly diversify into high-tech fields and patent products within these areas. However, both contributions focus on the patenting activity of very large LMT firms and it is questionable whether a similar pattern is evident among SMEs – at least the importance of patents is limited among the firms interviewed for this study. Yet, the frequency of joint innovation projects between high- and low-tech firms is high among the firms interviewed. Following Jensen et al. (2007), it shows how it is often necessary to combine the STI and DUI modes of innovation, in these instances by creating inter-firm collaborations. Thus, the following three cases exemplify how LMT firms today often are heavily involved in high-tech firms' innovation processes.

The first example is a British manufacturer of plastic products that has increasingly been targeting the pharmaceutical industry, both in terms of construction of clean rooms and production of drug delivery devices. The firm identified a lack of plastic-specific knowledge among many pharmaceutical firms and has during the last decade become heavily involved in collaborative innovation projects in areas spanning from medical devices to production facilities, most notably clean rooms. The firm's Business Development Manager emphasised that the collaborations led to results which would be beyond the reach of the firms individually: production time had for instance been reduced by one half on some products by combining the R&D efforts of pharmaceutical firms with the plastic producer's knowledge on materials. Naturally, a halved production time is crucial for firms in the pharmaceutical industry, where a fast or slow market entry can make the difference between a commercial success and failure. Furthermore, this collaboration was also of great value to the plastic manufacturer, who received access to unique knowledge and references:

> "The knowledge we gained in this partnership is now providing us with a competitive advantage. We have just negotiated a similar project where time is also an important factor. It was very beneficial for us to be able to prove that we have managed such a project before."

Business Development Manager, British plastics firm

This case exemplifies the potential mutual benefits to high- and low-tech firms of such collaborations – both in terms of execution time, knowledge build-up and market access.

Further examples derive from several major UK manufactures of metal products which have joined forces by acquiring a software development firm. The subsidiary specialises in software used for the design and production of steel beams which is given away for free in order to sell the products of the four parent firms. According to the General Manager, innovations are here again a product of R&D carried out in the software development firm combined with the knowledge of materials and production techniques in the fabricated metal firms. As the following quote demonstrates, it was initially necessary to devote time and resources to the collaboration; however it was a good long term investment:

> "At first we had to learn to speak the same language, but this ability is now one of our key assets."
>
> General Manager, British fabricated metal firm

The interactions between the parents and the subsidiary illustrate well the functioning of the chain-linked model of innovation: the parents initiate development projects when they detect new market needs e.g. the ability of the software to optimise the trade off between weight, insulation and fire protection. Naturally, the software development itself is carried out by the subsidiary, but employees from the parent companies are constantly involved in the project to ensure that the characteristics of the steel are adequately simulated in the software. Following this, the parent companies take the software through a testing phase, before the final adjustments are made by the subsidiary, and it is ready for distribution among the customers. This illustrates how intense communication between people with very different competencies is taking place in various stages of the production process.

The final example is a Danish firm producing stainless steel products. This firm has signed development contracts with its closest technological suppliers, which gives exclusive rights or at least advantageous sourcing conditions to the products developed under these agreements. Consequently, the firm's Project Manager describes the suppliers as "an ad hoc pool of development staff". In this case, the LMT firms act as a demanding customer (following von Hippel (1988)) who directly funds research in high-tech industries. Yet again, this underlines how LMT firms also stimulate economic development in research intensive industries as well as the complexity of innovation processes: here, the starting point is the production processes of the LMT-firm, not research in high-tech firms.

In addition to the value of common innovation projects, the interviews also pointed to the importance of the LMT firms' role as "translators" between end customers and research intensive suppliers. Manufactures of machinery often have to develop new products on the basis of perceived needs of end customers, but this can be avoided by building a strong network among producers of intermediary products:

> "We are often the connecting link between the desires of our customers and the work of our suppliers [of machinery]."
>
> Head of Production, Danish fabricated metal firm

LMT firms can in this way collect valuable information, which is costly or even unattainable for high-tech firms, that allows the identification of new commercial possibilities throughout the value chain.

Innovative collaborations between high- and low-tech firms are in this way becoming increasingly widespread. It is therefore not surprising that it is stressed by our interviewees that one of the greatest disadvantages of the British fabricated metal sector is the decline in the UK of the machinery industry which is of vital importance for the diffusion of R&D:

> "The UK metal industry has lost its machine makers and therefore finds it more difficult than previously to undertake many types of innovation projects. Today, a lot of the R&D knowledge in those areas is gone."

Director, British industrial organisation

This exemplifies the value of a mixed industrial environment which enables firms to benefit from different modes of innovation. In line with this, it was often stressed in the interviews that geographical proximity was highly important in specific stages of the high-/low-tech collaborations, especially the actual product design phase. A partnership between two firms from distant parts of Denmark was described as difficult, exactly because of the distance:

> "It is difficult to work efficiently with them on constructing the parts when we cannot just drop by each other. We try to compensate by arranging full day meetings quite frequently where we use rapid prototyping, but the meetings are often too short or at the wrong moment in the process."

Technical Director, Danish fabricated metal firm

In this specific case, the LMT-firm described the high-tech firm as "the state of the art" within their field, but they nevertheless considered finding a new partner firm within closer distance from themselves. Other LMT-firms explicitly mentioned co-location with partner firms as an important asset in the development projects.

> "We all have to be present when we do the testing – and we do many tests – so it only works since we are located so close to one another."

Product Manager, Danish plastics firm

Again, these observations highlight how innovations are produced in close collaboration between firms with very diverse knowledge bases, but they also emphasise the benefits of a varied industrial ecology – both for high- and low-tech firms. The rationale for high-tech firms to enter into product development projects with low-tech firms is often the low-tech firms' knowledge about materials and engineering techniques – their synthetic knowledge base. Our interviews show that physical co-presence is most often needed to access this knowledge. Thus, the interdependency of industries indicates that there are certain benefits associated with supporting a diverse industrial composition, including both high- and low-tech firms.

Discussion and conclusion

In the paper we have argued that a broader view of innovation is needed, including further emphasis on the relations between low-tech and high-tech firms, to get a better understanding of long term growth and regional development. Thus there should be a greater emphasis on the interconnectedness of industries rather than exaggerating the importance of R&D. The development since 1995 shows that the direct economic importance of high-tech industries is limited and stable, but still policymakers and many researchers continue to focus on research intensive industries. The current policy priorities continue to be inspired by the linear model of innovation and they are, firstly, likely to have sub-optimal effects in terms of growth stimulation due to a lack of attention given to a very large part of the economy and, secondly, liable to increase inter-regional inequality as they do not take the heterogeneity of regions in Europe into consideration.

It has previously been suggested that the pure form of the linear model of innovation encourages uneven development and a clear spatial division of labour – inter- as well as intra-nationally (Henry et al., 1995). Flows of values are shaped and governed by global inter- and intra-firm linkages of firms based in prosperous regions (Hadjimichalis and Hudson, 2007). By focusing strongly on R&D, policy programmes are biased towards large firms in core urban areas of the EU with cross-border contact networks. Thus, they lead to a strengthening of the R&D capacity of the most advanced regions as well as to industrial concentration in regions with a sufficient supply of skilled labour, information and business service (Amin and Tomaney, 1995; Markusen, 1996).

The inability of peripheral regions to compete for high-tech industries is due to both the current industrial composition of these regions as well as a lack of a suitable institutional environment. Not all regions have the necessary entrepreneurial and social traditions and it is difficult to create these through policy initiatives (Amin and Thrift, 1994; Hudson, 1997). Furthermore, successful and well-endowed regions are seeking to shape the EU policy agenda in their favour, focusing on R&D and advanced manufacturing rather than inter-regional equality (Hudson, 1997). The analysis presented in the paper indicates that their effort has been successful.

In a series of case studies, Markusen (1996) shows how the compatibility of regional and industrial policies is often low, especially for industries with great agglomeration economies and economies of scale. The experiences from Brazil, Japan, South Korea and the US shows how policy shifts towards high-tech industries have in all instances been associated with the concentration of economic development in a limited number of urban centres. Regional policy has been subordinated to industrial policy leading to a reinforcement of the advantages of prosperous regions. In terms of science policy there is also a coincidence of the interests of prosperous regions and national governments. Changes in governance of science policy have not led to greater regional equality – on the contrary, resources are becoming more concentrated and "only certain regions can succeed in the global race to become 'science regions'" (Perry and May, 2007; p. 1047).

What we suggest as an alternative to the current policy agenda is a greater focus on stimulating cooperation between industries with high and low research intensity as a way of targeting inter-regional inequality. Establishing such a policy focus would allow the inclusion of firms and institutions from peripheral regions to a much larger extent than the case today where regional policy increasingly has to give way to (high-tech focused) industrial policy and science policy. The attractiveness of this approach is also due to the endogenous character of development, which does not depend on the ability of the peripheral regions to develop institutional structures similar to those found in prosperous urban agglomerations, as well as the attention it pays to the importance of different industries in different parts of growth cycles (Lundquist et al., 2008).

A final issue worth reflecting upon is the importance of spatial distance between high- and low-tech firms engaged in collaborations. This constitutes an important direction of further enquiry as there is a need for a greater understanding of the character of relations between high- and low-tech firms. Questions remain about the potential for firms to get engaged in development and learning collaborations across industries and distance. An initial hypothesis might be that geographical proximity is of primary importance for such collaborations as relational proximity is assumed to be low between firms from very dissimilar industries. Gertler's work on collective learning by users and producers of advanced manufacturing technology and the importance of geographical and cultural proximity in facilitating such collaborations supports this theory (Gertler, 1995; 1996; Gertler and DiGiovanna, 1997). On the other hand, some low-tech firms in peripheral regions are capable of tapping into external knowledge flows through collaboration with research institutions and firms with higher technological intensity (Giuliani and Bell, 2005). Future research contributions ought to analyse the mechanisms facilitating these partnerships. Is the relational proximity greater than expected? Do low-tech firms gain access to R&D through subsidiaries in urban growth regions? Do high-tech firms access tacit and skill-intensive knowledge through branches in peripheral areas?

Irrespective of the outcome of such analyses, strengthening relational proximity between high- and low-tech firms is an area of great importance. This paper also shows the necessity of challenging the foundations of policymaking to ensure that outdated understandings of industrial linkages (the linear model of innovation) give way to newer ones (e.g. the chain-linked model of innovation) which offer greater theoretical insights. In the worst case, a continuing focus on R&D will result in, firstly, a decline of European low-tech industries and the regions where these are concentrated. Secondly, in the longer run it might also harm the development of high-tech industries if the most innovative low-tech industries are found in other parts of the world, thus increasing the difficulty of establishing collaborations. Consequently, there are several reasons for implementing a more inclusive European industrial policy.

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References

Amin, A. & Cohendet, P. (2004) *Architectures of Knowledge: Firms, Capabilities and Communities* Oxford, Oxford University Press.

Amin, A. & Thrift, N. (1994) Living in the Global. In: A. Amin & N. Thrift (eds.) *Globalization, Institutions, and Regional Development in Europe*. Oxford: Oxford University Press, pp. 1-22.

Amin, A. & Tomaney, J. (1995) The Regional Dilemma in a Neo-Liberal Europe. *European Urban and Regional Studies*, 2, (2) 171-188.

Arditi, D., Kale, S., & Tangkar, M. (1997) Innovation in construction equipment and its flow into the construction industry. *Journal of Construction Engineering and Management-Asce*, 123, (4) 371-378.

Asheim, B. T. (2009) Regional Endowment. In: J. Potter & G. Miranda (eds.) *Entrepreneurship and the Innovation System of the Agder Region, Norway*. Paris: OECD, pp. 151-173.

Asheim, B. T. & Coenen, L. (2006) The role of regional innovation systems in a globalising economy. Comparing knowledge bases and institutional frameworks of Nordic clusters. In: G. Vertova (ed.) *The Changing Economic Geography of Globalization*. Abingdon: Routledge, pp. 148-165.

Asheim, B. T. & Gertler, M. S. (2005) The Geography of Innovation: Regional Innovation Systems. In: J. Fagerberg, D. C. Mowery, & R. R. Nelson (eds.) *The Oxford Handbook of Innovation*. Oxford: Oxford University Press, pp. 291-317.

Bar-El, R. & Felsenstein, D. (1989) Technological Profile and Industrial-Structure - Implications for the Development of Sophisticated Industry in Peripheral Areas. *Regional Studies*, 23, (3) 253-266.

Bender, G. & Laestadius, S. (2005) Non-science based innovativeness. On capabilities relevant to generate profitable novelty. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, (1-2) 124-170.

Birch, K., MacKinnon, D., & Cumbers, A. (2010) Old Industrial Regions in Europe: A Comparative Assessment of Economic Performance. *Regional Studies*, 44, (1) 35-53.

Boltho, A. (2003) What's wrong with Europe? *New Left Review* (22) 5-26.

Bush, V. (1945) *Science: The Endless Frontier* Washington, United States Government Printing Office.

Chen, L.C. (2009) Learning through informal local and global linkages: The case of Taiwan's machine tool industry. *Research Policy*, 38, (3) 527-535.

Cooke, P. (2001) Regional Innovation Systems, Clusters, and the Knowledge Economy. *Ind Corp Change*, 10, (4) 945-974.

Cooke, P. & Morgan, K. (1998) *The Associational Economy: Firms, Regions, and Innovation* Oxford, Oxford University Press.

David, P.A. & Foray, D. (2002) An introduction to the economy of the knowledge society. *International Social Science Journal*, 54, (1) 9-23.

Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., & Soete, L. (1988) *Tecnical Change and Economic Theory* London, Pinter Publishers.

Dunford, M. (2005a) Growth, inequality and cohesion: A comment on the Sapir Report. *Regional Studies*, 39, (7) 972-978.

Dunford, M. (2005b) Old Europe, new Europe and the USA - Comparative economic performance, inequality and market-led models of development. *European Urban and Regional Studies*, 12, (2) 149-176.

Edgerton, D. (2004) "The Linear Model Did Not Exist": Reflections on the history and historiography of science and research in industry in the twentieth century. In: K. Gradin, N. Wormbs, & S. Widmalm (eds.) *The Science-Industry Nexus. History, Policy, Implications*. Sagamore Beach: Science History Publications/USA, pp. 31-57.

Edquist, C. (1997) *Systems of Innovation: Technologies, Institutions and Organizations* London, Pinter.

European Commission (2004) *Facing the challenge: The Lisbon strategy for growth and employment*, European Commission, Bruxelles.

European Commission (2006a) *Constructing Regional Advantage*, European Commission, Bruxelles.

European Commission (2006b) *Creating an Innovative Europe*, European Commission, Bruxelles.

European Commission (2008) *A more research-intensive and integrated European Research Area*, European Commission, Bruxelles.

Eurostat (2009) *'High-technology' and 'knowledge based services' aggregations based on NACE Rev. 2* Luxembourg.

Fagerberg, J. (2005) Innovation: A Guide to the Literature. In: J. Fagerberg, D. C. Mowery, & R. R. Nelson (eds.) *The Oxford Handbook of Innovation*. Oxford: Oxford University Press, pp. 1-26.

Gertler, M.S. (1995) Being There - Proximity, Organization, and Culture in the Development and Adoption of Advanced Manufacturing Technologies. *Economic Geography*, 71, (1) 1-26.

Gertler, M.S. (1996) Worlds apart: The changing market geography of the German machinery industry. *Small Business Economics*, 8, (2) 87-106.

Gertler, M.S. & DiGiovanna, S. (1997) In search of the new social economy: collaborative relations between users and producers of advanced manufacturing technologies. *Environment and Planning A*, 29, (9) 1585-1602.

Giuliani, E. & Bell, M. (2005) The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster. *Research Policy*, 34, (1) 47-68.

Godin, B. (2006) The linear model of innovation - The historical construction of an analytical framework. *Science Technology & Human Values*, 31, (6) 639-667.

Gordon, R. (2004) Two Centuries of Economic Growth: Europe Chasing the American Frontier. *CEPR Discussion Papers*.

Hadjimichalis, C. & Hudson, R. (2007) Rethinking local and regional development - Implications for radical political practice in Europe. *European Urban and Regional Studies*, 14, (2) 99-113.

Hansen, H.K. & Winther, L. (2010) The Spatial Division of Talent in City Regions: Location Dynamics of Business Services in Copenhagen. *Tijdschrift voor Economische en Sociale Geografie*, 101, (1) 55-72.

Hansen, T. (2010) The Danish fabricated metal industry: A competitive medium-low-tech industry in a high-wage country. *Danish Journal of Geography*, 110, (1) 65-80.

Hanson, J. (2008) Fra silisium til solceller – fremveksten av norsk solcelleindustri. In: J. Hanson & O. Wicken (eds.) *Rik på natur. Innovasjon i en ressursbasert kunnskapsøkonomi*. Bergen: Fagbokforlaget, pp. 43-58.

Heidenreich, M. (2009) Innovation patterns and location of European low- and medium-technology industries. *Research Policy*, 38, (3) 483-494.

Henry, N., Massey, D., & Wield, D. (1995) Along the Road - R-And-D, Society and Space. *Research Policy*, 24, (5) 707-726.

Hirsch-Kreinsen, H. (2005) Low-Tech Industries: Innovativeness and Development Perspectives. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, (1-2) 19-48.

Hirsch-Kreinsen, H. (2008) 'Low-Tech' Innovations. *Industry & Innovation*, 15, (1) 19-43.

Hirsch-Kreinsen, H., Jacobson, D., & Robertson, P.L. (2006) 'Low-tech' Industries: Innovativeness and Development Perspectives - A Summary of a European Research Project. *Prometheus: Critical Studies in Innovation*, 24, (1) 3-21.

Hollanders, H., Tarantola, S., & Loschky, A. (2009) *Regional Innovation Scoreboard 2009*, Pro Inno Europe, Bruxelles.

Hudson, R. (1997) Regional futures: Industrial restructuring, new high volume production concepts and spatial development strategies in the new Europe. *Regional Studies*, 31, (5) 467-478.

Jacobson, D. & Heanue, K. (2005) Policy conclusions and recommendations. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, (1-2) 359-416.

Jensen, M.B., Johnson, B., Lorenz, E., & Lundvall, B.A. (2007) Forms of knowledge and modes of innovation. *Research Policy*, 36, (5) 680-693.

Kaloudis, A., Sandven, T., & Smith, K. (2005) Structural change, growth and innovation: The roles of medium and low tech industries, 1980-2002. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, (1-2) 49-74.

Kirner, E., Kinkel, S., & Jaeger, A. (2009) Innovation paths and the innovation performance of low-technology firms - An empirical analysis of German industry. *Research Policy*, 38, (3) 447-458.

Kline, S. J. & Rosenberg, N. (1986) An Overview of Innovation. In: R. Landau & N. Rosenberg (eds.) *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington DC: National Academy Press, pp. 275-304.

Laestadius, S., Pedersen, T.E., & Sandven, T. (2005) Towards a new understanding of innovativeness - and of innovation based indicators. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, (1-2) 75-121.

Lundquist, K.J., Olander, L.O., & Henning, M.S. (2008) Decomposing the technology shift: Evidence from the Swedish manufacturing sector. *Tijdschrift voor Economische en Sociale Geografie*, 99, (2) 145-159.

Lundvall, B.A. (1992) *National Systems of Innovation* London, Pinter.

Markusen, A. (1996) Interaction between regional and industrial policies: Evidence from four countries. *International Regional Science Review*, 19, (1-2) 49-77.

Maskell, P. & Malmberg, A. (1999) The competitiveness of firms and regions - 'Ubiquitification' and the importance of localized learning. *European Urban and Regional Studies*, 6, (1) 9-25.

Mendonca, S. (2009) Brave old world: Accounting for 'high-tech' knowledge in 'low-tech' industries. *Research Policy*, 38, (3) 470-482.

Morgan, K. (1997) The learning region: Institutions, innovation and regional renewal. *Regional Studies*, 31, (5) 491-503.

Nelson, R.R. & Winter, S.G. (1982) *An Evolutionary Theory of Economic Change* Cambridge, The Belknap Press of Harvard University Press.

Nonaka, I. & Takeuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation* Oxford, Oxford University Press.

Nonaka, I., Takeuchi, H., & Umemoto, K. (1996) A theory of organizational knowledge creation. *International Journal of Technology Management*, 11, (7-8) 833-845.

OECD (2002) *The Measurement of Scientific and Technological Activities - Proposed Standard Practice for Surveys of Research and Experimental Development: Frascati Manual*, OECD, Paris.

OECD (2004) *High-Tech trade, Employment and Value Added in High-Tech Industries and Knowledge-Intensive Services*, OECD, Paris, 2.

OECD (2007) *OECD Science, Technology and Industry Scoreboard 2007*, OECD, Paris.

OECD (2009) *2009 Interim Report on the OECD Innovation Strategy. An Agenda for Policy Action on Innovation*, OECD, Paris.

ONS (2010) *UK Business: Activity,Size and Location – 2010*, ONS, London.

Patrucco, P.P. (2005) The emergence of technology systems: knowledge production and distribution in the case of the Emilian plastics district. *Cambridge Journal of Economics*, 29, (1) 37-56.

Pavitt, K. (1984) Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, 13, (6) 343-373.

Perry, B. & May, T. (2007) Governance, Science Policy and Regions: An Introduction. *Regional Studies*, 41, (8) 1039-1050.

Radauer, A. & Streicher, J. (2007) Low-Tech, innovation and state aid: the Austrian case. *International Entrepreneurship and Management Journal*, 3, (3) 247-261.

Rigby, D. L. (2003) Geography and Technological Change. In: E. Sheppard & T. J. Barnes (eds.) *A Companion to Economic Geography*. Malden: Blackwell Publishing, pp. 202-223.

Robertson, P.L. & Patel, P.R. (2005) New wine in old bottles. Technological diffusion in developed economies. *Perspectives on Economic, Political and Social Integration*, Special Edition XI, 271-304.

Robson, M., Townsend, J., & Pavitt, K. (1988) Sectoral Patterns of Production and Use of Innovations in the UK - 1945-1983. *Research Policy*, 17, (1) 1-14.

Santamaria, L., Nieto, M.J., & Barge-Gil, A. (2009) Beyond formal R&D: Taking advantage of other sources of innovation in low- and medium-technology industries. *Research Policy*, 38, (3) 507-517.

Sapir, A., Aghion, P., Bertola, G., Hellwig, M., Pisani-Ferry, J., Rosati, D., Viñals, J., & Wallace, H. (2003) *An agenda for a growing Europe: the Sapir report*, European Commission, Bruxelles.

Scherer, F.M. (1982) Inter-Industry Technology Flows in the United-States. *Research Policy*, 11, (4) 227-245.

Schumpeter, J. (1943) *Capitalism, Socialism and Democracy* New York, Harper & Row.

Scott, A.J. (2008) *Social Economy of the Metropolis* Oxford, Oxford University Press.

Smith, K. (2005) Measuring Innovation. In: J. Fagerberg, D. C. Mowery, & R. R. Nelson (eds.) *The Oxford Handbook of Innovation*. Oxford: Oxford University Press, pp. 148-177.

Statistics Denmark (2009) *Statistics on national accounts, balance of payments and international investment position*.

Storper, M. (1997) *The Regional World: Territorial Development in a Global Economy* New York, The Guildford Press.

Turok, I. (2004) Cities, regions and competitiveness. *Regional Studies*, 38, (9) 1069-1083.

von Hippel, E. (1988) *The sources of innovation* New York, Oxford University Press.