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Competitive low-tech manufacturing and challenges for regional policy in the European context – lessons from the Danish experience

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Competitive low-tech manufacturing and challenges for regional policy in the European context – lessons from the Danish experience

Abstract

Today, low-tech firms in high-wage countries are focusing on increasing investments in highly skilled labour and advanced machinery, incremental innovation and high value-added niches. Danish policy, however, gives little attention to the new specificities of low-tech manufacturing, and the understanding of innovation in national and regional strategies is dominated by a science-based perspective. There is a strong policy focus on human capital and R&D in manufacturing. Human capital is vital to manufacturing in general, but the latter is of less importance for low-tech firms. Conversely, user-producer interactions and machinery investments, which are critical to low-tech competitiveness, are disregarded by policies.

Keywords

Low-tech manufacturing, regional policy, regional development, innovation, competitiveness

JEL codes

L60, O31, R58

Introduction

In the process of rebuilding the Western economies after the economic crisis, it is assumed that manufacturing will play a central role. However, the focus of attention is not manufacturing as a whole, but rather a specific subcategory of manufacturing, namely high-tech industries (Pisano and Shih 2009). In line with this, from an EU policy perspective, promoting high-tech industries through research and development (R&D) investments is regarded as crucial to securing a competitive manufacturing industry (European Commission 2008). This reasoning has recently been questioned by a growing literature on the development of low-tech manufacturing in high-wage countries which highlights that non-R&D intensive industries maintain significant economic importance in European countries (Kaloudis et al. 2005; Hansen and Winther 2011). No systematic review of this literature has been carried out so far, however, many studies point out that low-tech firms are not passively waiting to be outcompeted by firms from low-cost countries, but employ various strategies to remain competitive (Hirsch-Kreinsen 2008a). Thus, the character and activities of these industries are profoundly changing: the labour intensive low-tech firms of yesterday are gradually replaced by low-tech firms focusing on high value-added niches with increasing investments in highly skilled labour, advanced machinery and even R&D.

In light of this, the contribution of this paper is twofold. Firstly, it critically synthesises the main conclusions from the recent literature on the development of low-tech manufacturing, giving specific attention to the role assigned to public policy in supporting these industries. Secondly, it empirically assesses whether public policy takes the specificities and changing character of low-tech manufacturing into account, by examining Danish innovation and regional industrial development policies. Denmark provides an interesting case as low-tech manufacturing remains of high economic importance. Based on the review, we clarify which policies that according to the literature are needed to support low-tech manufacturing in the regions of the advanced economies, and we compare these insights to the Danish policies.

The structure of the paper is as follows. In section two, we review the recent years' insights on the development of low-tech manufacturing. Based on this, in section three, we synthesise the recommendations by the literature on the needs that current public policy must address to support the further development of low-tech manufacturing in high-wage countries. Section four initially provides a short introduction to the Danish manufacturing economy, followed by a systematic analysis of the extent to which Danish innovation and regional industrial development policies give attention to the requirements of low-tech manufacturing. Discussion and conclusion are provided in the final section.

Development of low-tech manufacturing

In this paper, we focus on the development of low-tech manufacturing, defined as manufacturing industries with R&D intensity below 3% (equivalent to low-tech and medium-low-tech manufacturing industries in the OECD (2005) classification). While the R&D intensity of industries is an important characteristic, there is a need for a broader conceptualisation of manufacturing in the knowledge economy that pays attention to, among other things, human capital levels and capital investments (e.g. Pavitt 1984; Bar-El and Felsenstein 1989; Laestadius et al. 2005; Asheim 2007). Thus, it is in fact more important to apprehend variations between industries in the types of critical knowledge and the ways this knowledge is sourced, than to attempt to rank industries according to their knowledge intensity. Arguably, it is difficult to find manufacturing industries located in high-wage economies, which are not knowledge intensive, and industrial taxonomies should reflect this. Although the institutionalisation of the low-tech/high-tech categorisation in policy circles makes it very likely that the taxonomy will maintain importance in the years to come, it is important to look beyond R&D intensity and analyse broader forms of knowledge sourcing and use. This review provides such a critical overview of the literature on low-tech manufacturing. We have an exclusive focus on the recent transformation of low-tech manufacturing, although, we recognise that mature industries and low-tech manufacturing have attracted considerable interest since the 1970s including the relocation and specialisation debate, the industrial district literature and later the focus on learning regions and

clusters. In Scandinavia there was an interest in low-tech manufacturing from a localised learning perspective in the 1990s, for instance the competitiveness of the furniture industry (Eskelinen 1997; Maskell 1998; Maskell et al. 1998).

To review and synthesise the recent years' contributions on this topic, we identified relevant papers in Thomson Reuters' Social Sciences Citation Index database for the period 2000-2013.^{1 2} Following this, contributions on topics of little relevance for the current paper as well as empirical studies from developing countries and papers on non-manufacturing industries were disregarded for the analysis. Finally, a number of key contributions such as the book edited by Hirsch-Kreinsen and Jacobson (2008) were added to the list, resulting in a total number of 84 contributions. The 84 contributions are very diverse in terms of focus, methodology and geography, but they are in general European based, national studies of which many are using quantitative methodologies, although there are cases studies of specific industries and particular geographies. Despite the diversity, it is possible to identify key issues of the transformation and characteristics of low-tech manufacturing, albeit acknowledging the underlying diversity between low-tech industries and geographies including the national and regional institutional set-ups. Each contribution was analysed and summarised into key categories; low-tech innovation strategies, firm investments, firms relations and agglomeration economies. Within each of these categories, the main conclusions and insights were synthesised – see table 1.

Table 1. Summary of research on the development of low-tech manufacturing

Topic	Contributions	Main insights
Innovation strategies	Boly et al. (2000); McGahan and Silverman (2001); O'Regan and Ghobadian (2005); Bierly and Daly (2007); Bryson et al. (2008); Hirsch-Kreinsen (2008a; 2008b); Heidenreich (2009); Kirner et al. (2009); Santamaria et al. (2009); Belso-Martinez (2010); Hansen (2010); Bathelt et al. (2011); Cefis and Marsili (2011); Hervas-Oliver et al. (2011b); Ismail et al. (2011); Clausen et al. (2012)	<ul style="list-style-type: none"> • Low-tech innovation strategies focus on incremental improvements of products and production processes as well as customisation of products • Increasing emphasis on specialisation in high value-added niche markets • Focus on high product quality, high operational efficiency and low scrap rates
Human capital	Hollanders and ter Weel (2002); Bender and Laestadius (2005); Schmierl and Holm-Detlev (2005); Hirsch-Kreinsen et al. (2006); Thornhill (2006); Vaz et al. (2006); Corbett (2008); Santamaria et al. (2009); Hansen (2010); Hervas-Oliver et al. (2011b); Hervas-Oliver et al. (2012); Giannetti and Madia (2013); Hatch (2013); Mion and Zhu (2013); Hansen et al. (2014)	<ul style="list-style-type: none"> • Human capital is increasingly important for low-tech manufacturing • This reflects intensifying competition which drives technical change • Investments in training is positively associated with innovativeness of low-tech firms • Highly skilled employees facilitate collaboration with high-tech firms
Capital investments	Hollanders and ter Weel (2002); Schmierl and Holm-Detlev (2005); Corbett (2008); McAfee and Brynjolfsson (2008); Ghosal and Nair-Reichert (2009); Heidenreich (2009); Santamaria et al. (2009); Hansen (2010); Hervas-Oliver et al. (2011b); Kumbhakar et al. (2012); Hatch (2013); Mion and Zhu (2013); Hansen and Winther (2014)	<ul style="list-style-type: none"> • Machinery investments increase considerably in low-tech manufacturing • Such investments are of significant importance for low-tech competitiveness
R&D investments	González and Pazó (2008); Kafouros (2008); Grimpe and Sofka (2009); Mendonça (2009); Hervas-Oliver et al. (2011b); Ortega-Argilés et al. (2011); Czarnitzki and Thorwarth (2012); De Beule and Van Beveren (2012)	<ul style="list-style-type: none"> • Large low-tech firms increasingly diversify into new technologies • R&D investments stimulate low-tech innovativeness, but less than in high-tech • Economic payoff to R&D is higher in low-tech manufacturing than in high-tech
Relations outside value chains	Vence et al. (2000); Schartinger et al. (2002); Blanes and Busom (2004); Chesbrough and Crowther (2006); Radauer and Streicher (2007); Gerybadze and Slowak (2008); Hirsch-Kreinsen (2008a); Mendonça (2009); Frykfors and Jönsson (2010); Spithoven et al. (2010); Hansen and Winther (2011); Hervas-Oliver et al. (2011a; 2012); Trippel (2011); Eisingerich et al. (2012); Spithoven and Knockaert (2012)	<ul style="list-style-type: none"> • Character of relations are significantly different from the ones found in high-tech • University relations are e.g. predicted by other factors and concerned with other issues than for high-tech firms • Relations to collective research centres and standard setting organisations are also of significant importance to low-tech firms
Supplier and	Boly et al. (2000); Garibaldo and Jacobson (2005); Robertson and Patel	<ul style="list-style-type: none"> • Suppliers – from research-intensive industries – are key sources of knowledge and

customer relations	(2005); Hirsch-Kreinsen et al. (2006); Di Maria and Finotto (2008); Hirsch-Kreinsen (2008a); Albors-Garrigós et al. (2009); Grimpe and Sofka (2009); Hauknes and Knell (2009); Heidenreich (2009); Kok and Biemans (2009); Frykfors and Jönsson (2010); Bathelt et al. (2011); Hansen and Winther (2011); Hervas-Oliver et al. (2011b; 2012); Tripl (2011); Grosse and Fonseca (2012); Segarra-Ciprés et al. (2012)	<p>inputs for low-tech manufacturing</p> <ul style="list-style-type: none"> • Conversely, low-tech manufacturing industries are main markets for high-tech products, and low-tech firms often play key roles in the development of these • The role of customers for the innovativeness of low-tech firms is crucial and increasing over time
Agglomeration	Brühlhart (2001); Hackler (2003); Alonso-Villar et al. (2004); Devereux et al. (2004); Barrios et al. (2006); Molina-Morales and Martínez-Fernández (2006); Scott (2006); Teixeira et al. (2008); Arauzo-Carod and Viladecans-Marsal (2009); Pla-Barber and Puig (2009); Val et al. (2009); Audia and Rider (2010); Neffke et al. (2010); De Beule and Van Beveren (2012); Hartog et al. (2012)	<ul style="list-style-type: none"> • Low-tech manufacturing benefits from localisation economies rather than urbanisation economies • Low-tech industries are more geographically clustered than high-tech • Low-tech manufacturing depends primarily on local relations – MAR externalities

A number of contributions suggest that low-tech firms follow **innovation strategies** that are significantly different from those in high-tech firms. Following the knowledge base taxonomy (Asheim 2007), which highlights differences between industries in the types of knowledge that are crucial for economic activity, low-tech industries have predominantly synthetic knowledge bases, implying that innovations are often based on existing knowledge. Tacit knowledge acquired through learning-by-doing and learning-by-using is therefore central to innovation processes, leading to, for instance, an emphasis on constantly developing new designs based on existing products that are often tailored to the demands of specific customers (Asheim and Coenen 2005). In contrast, high-tech industries are characterised by analytical knowledge bases where codified knowledge is both a major input and output of the knowledge creation process, and where scientific methods and modelling are central to the creation of innovations. In line with this, it is argued that low-tech innovation strategies focus more on incremental than radical innovations (Hirsch-Kreinsen 2008a; Hansen 2010). Incremental improvements of products and production processes result in high product quality, high operational efficiency and low scrap rates (Boly et al. 2000; Bierly and Daly 2007; Kirner et al. 2009; Ismail et al. 2011). Process innovation is central to the development and survival of low-tech firms, and process innovation is highly persistent in low-tech manufacturing (Heidenreich 2009; Kirner et al. 2009; Cefis and Marsili 2011; Hervas-Oliver et al. 2011b; Clausen et al. 2012). An additional development in low-tech innovation strategies is the increasing emphasis on specialisation and customisation which allows low-tech firms to focus on high value-added niche markets (Bryson et al. 2008; Belso-Martinez 2010; Hansen 2010). This also highlights the increasing significance of design, i.e. detailed development necessary to translate prototype into product (Marsili and Salter 2006), which allow low-tech firms to develop customer-specific solutions (Bender and Laestadius 2005; Santamaria et al. 2009; Bathelt et al. 2011; Hervas-Oliver et al. 2011b). In the following we review studies that examine specific aspects of the overall transformation of low-tech industries and firms.

An important topic in the literature on low-tech manufacturing has been the role of **human capital**. Hansen et al. (2014) highlight that human capital, in the form of highly skilled labour, is increasingly important in low-tech manufacturing, and that the growth in the low-tech manufacturing's use of

highly skilled labour is in fact significantly higher than in medium- and high-tech manufacturing. This reflects the increasing sophistication of production processes in low-tech firms in developed countries, resulting from intensifying global competition (Bhattacharya and Bloch 2004). Competition from low-wage countries stimulates technical change in low-tech manufacturing, which may lead to small employment declines (Michel and Rycx 2012), but also to a significant upgrading of human capital (Mion and Zhu 2013). The accelerating substitution of machinery for labour reduces employment of unskilled labour, and the operation and maintenance of advanced machinery require increasingly higher skill levels of employees. Thus, low-tech firms with highly qualified personnel are more innovative (Vaz et al. 2006) and investment in training and upgrading of employees' skills is positively associated with revenue growth (Thornhill 2006), increased sales (Corbett 2008) and innovativeness (Santamaria et al. 2009; Hervas-Oliver et al. 2011b; Giannetti and Madia 2013). Further, highly skilled labour also facilitates collaboration with high-tech firms (Hervas-Oliver et al. 2012). To enter such collaborations, high-tech firms often require that some highly skilled employees work in development positions in the low-tech firms to ensure that work routines are not too dissimilar between the partners (Hansen 2012). Finally, it should be noted that shortages of skilled labour, and discrepancy between competencies provided by standard educational programs and those demanded by low-tech firms are both found to be important challenges for low-tech manufacturing (Schmierl and Holm-Detlev 2005; Hansen 2010). This reflects the argument by Christopherson and Clark (2007) that while employees with PhD degrees are not necessary in all industries, medium-skilled labour is increasingly becoming a minimum requirement across different types of industries. Thus, the literature focuses mainly on highly skilled labour, formal education and to some extent vocational training, while learning-by-doing and learning-by-using is overlooked despite the importance of such processes for the ability of manufacturing employees to contribute to problem solving and innovation (Lundvall and Nielsen 1999). An important exception is the paper by Hatch (2013), which emphasises the positive influence of on-the-job training on flexibility, ability to handle complex production processes and, eventually, success in the marketplace for low-tech firms.

The increasing importance of human capital is closely related to **capital investments** and the use of gradually more advanced machinery in low-tech manufacturing. As mentioned by Mion and Zhu (2013), technical change leads to increasing human capital levels, and Hatch (2013) finds that successful low-tech firms combine investments in human capital and machinery. According to Hollanders and ter Weel (2002), upgrading of human capital in low-tech manufacturing is driven by use of new technologies rather than development of new technologies. Machinery investments have increased considerably more in low-tech manufacturing than in medium- and high-tech manufacturing over the last decades, and low-tech firms surpass high-tech firms concerning the adoption of advanced manufacturing technologies (Hervas-Oliver et al. 2011b; Hansen and Winther 2014). Multiple studies point to the importance of such investments for low-tech competitiveness. Investments in physical capital significantly increase labour productivity (Kumbhakar et al. 2012), and productivity in general (Ghosal and Nair-Reichert 2009), use of advanced machinery is a critical explanatory factor of product and process innovations in low-tech – but not high-tech – firms (Santamaria et al. 2009), and acquisition of machinery, equipment and software is important for low-tech innovativeness and sales (Corbett 2008; McAfee and Brynjolfsson 2008; Heidenreich 2009). However, a case study of the fabricated metal industry in Denmark revealed that the growing sophistication and complexity of advanced machines make the processes of selecting new machinery increasingly challenging for low-tech firms (Hansen 2010). Thus, the literature points to the importance of capital investment for the competitiveness of low-tech firms, but less on the affordability issues of especially SMEs including financing and search and implementation cost of new machinery.

While the size of **R&D investments** is by definition limited in low-tech manufacturing, such investments may still be important for low-tech firms. McGahan and Silverman's (2001) analysis of innovation in the US reveals that the general level of patenting activity is not lower in mature industries compared to emerging industries. They also find no evidence of a shift from product to process innovation with industry maturity, and no evidence that leaders innovate less in mature industries than in non-mature industries. Large low-tech firms increasingly diversify into new

technologies (e.g. ICT and biotech), and patent nearly as much as large high-tech firms within these fields, thus, low-tech firms are important agents in the development of new technologies (Robertson and Smith 2008; Mendonça 2009). Additional studies consider the relation between R&D investments and innovativeness in low-tech manufacturing. Hervas-Oliver et al. (2011b) point out that product innovativeness is significantly influenced by R&D investments. Grimpe and Sofka (2009) find that low-tech innovativeness is stimulated by the combination of R&D investments and collaboration with customers. Further, the results of De Beule and Van Beveren (2012) and Ortega-Argilés et al. (2011) show that R&D investments have positive effects on innovativeness and labour productivity in all types of manufacturing industries, however, increasing with technological intensity. Importantly, this does not imply that R&D investments are more profitable in high-tech manufacturing. While Czarnitzki and Thorwarth (2012) find that basic research only exhibits a premium on financial performance in high-tech industries, Kafouros (2008) shows that even though the R&D process is carried out more effectively in high-tech firms, the economic payoff to R&D investments is in fact higher in low-tech firms, due to the less intensive R&D environment in low-tech manufacturing, which allows firms to benefit from R&D investments over longer time. In sum, the role of R&D investments in low-tech industries points to increasingly blurred boundaries between high- and low-tech manufacturing industries (see also Kirner et al. 2009).

One of the central questions analysed by work on low-tech manufacturing is the role of external relations for the innovativeness of firms. While some disagreement is found concerning the overall relative importance of external networks in low-tech (compare Garibaldi and Jacobson (2005) with Heidenreich (2009)), work on **linkages to actors outside value chains**ⁱⁱⁱ generally stress their importance to low-tech firms, but also that the character of these relations are significantly different from the ones found in high-tech (Vence et al. 2000; Blanes and Busom 2004; Chesbrough and Crowther 2006; Frykfors and Jönsson 2010). A case in point is relations to universities, where the content of the collaborations vary from high-tech manufacturing: even though R&D collaborations with local universities may be relevant for low-tech firms (Trippel 2011), high-tech firms are more likely to engage in contract research, but training courses and hiring of university researchers are of

significant importance for low-tech firms (Schartinger et al. 2002). The propensity of low-tech firms to collaborate with universities also depends on different factors than for high-tech firms. R&D expenditures and tax breaks have little influence while particularly the share of R&D employees is an important predictor (Hervas-Oliver et al. 2011a). The value of such university relations to low-tech firms is emphasised by Radauer and Streicher (2007) who also highlight that insufficient knowledge of support schemes and the excessively theoretical focus of these are main barriers for low-tech firms to engage in collaborations. Other important external relations for low-tech firms identified in the literature are collective research centres (Spithoven et al. 2010; Hervas-Oliver et al. 2012; Spithoven and Knockaert 2012) and standard setting organisations (Gerybadze and Slowak 2008). An important limitation to the low-tech literature on the importance of external relations for firm competitiveness is that almost all studies have a European focus. Hence, there is a lack of studies examining these issues in other high-wage economies with different institutional set-ups, which may impact the practices of low-tech firms (see Hatch 2013). However, this omission may also reflect that external relations are particularly important in the European context compared to, for instance, North America where interaction with universities and intermediaries are more limited (Gertler and Vinodrai 2005).

A main topic in the literature on low-tech manufacturing has been **relations to suppliers and customers**. Multiple contributions highlight the importance of suppliers as a source of new knowledge and inputs which would be difficult to obtain elsewhere (Boly et al. 2000; Garibaldo and Jacobson 2005; Hervas-Oliver et al. 2011b; Grosse and Fonseca 2012). Thus, suppliers from more research-intensive industries are important sources of innovativeness for low-tech firm (Robertson and Smith 2008; Heidenreich 2009; Trippel 2011; Hervas-Oliver et al. 2012). However, it is important to note that the relation between high- and low-tech firms is one of interdependency: low-tech manufacturing constitutes a main market for high-tech products and low-tech firms often play a central role in the development of these (Robertson and Patel 2005; Hauknes and Knell 2009; Hansen and Winther 2011). Concerning linkages to customers, there is general agreement in the literature that these are of key importance for low-tech firms, as they allow a detailed understanding of the (changing) needs of the market. Thus, user-producer interactions have become more important as low-tech firms

increasingly follow customisation and specialisation strategies to increase profitability, thus, very frequent contact with customers are necessary to learn and agree on product specifications and understand changing customer preferences (Frykfors and Jönsson 2010; Hansen 2010; Groth and Winther 2013). Further, as described by Bathelt et al. (2011), close collaboration with customers over time may eventually allows low-tech firms to become involved in early-stage product design and, thus, develop advanced design capabilities which support diversification. Low-tech firms are more market oriented in their knowledge linkages than high-tech firms (Grimpe and Sofka 2009; Kok and Biemans 2009) and the effect of collaboration with customers on innovativeness is significantly higher in low-tech manufacturing (Segarra-Ciprés et al. 2012). Effective communication with customers is important for net sales (Di Maria and Finotto 2008; Albors-Garrigós et al. 2009), and Garibaldo and Jacobson (2005) suggest that the importance for low-tech firms of close collaboration with customers becomes greater over time. An important limitation to the low-tech literature is that it often treats user-producer relations highly fragmented. It does not examine the knowledge relations between low-tech firms and customers over time and the resulting changes in learning processes in such user-producer relationships, which have been pointed out as essential in the literature on innovation systems and learning (Lundvall 1988; Lundvall and Johnson 1994).

Finally, several studies examine the impact of **agglomeration economies** on low-tech manufacturing. Strong evidence indicates that low-tech manufacturing primarily benefits from localisation economies (De Beule and Van Beveren 2012), while high-tech manufacturing mainly benefits from urbanisation economies. This is confirmed by Arauzo-Carod and Viladecans-Marsal (2009) at the intra-urban level. They also conclude that low-tech firms are located at a longer distance from the city centre compared to high- and medium-tech. At the regional level, an Irish study concludes that the location of low-tech firms seems to be only influenced by agglomeration economies created by MAR externalities (Barrios et al. 2006). This conclusion seems also to be the case for mature industries compared to young industries (Neffke et al. 2010) and for high-tech compared to low-tech industries (Alonso-Villar et al. 2004). Further, successful collaborative R&D projects in high-tech manufacturing are between culturally and geographically distant partners, while in low-tech manufacturing they are between

culturally and geographically close partners (Teixeira et al. 2008). The tendency of low-tech firms to cluster and the dependency on the local environment is confirmed by empirical studies in Spain (Molina-Morales and Martínez-Fernández 2006; Val et al. 2009), the UK (Devereux et al. 2004) and throughout Europe (Brülhart 2001). The importance of the local environment is also found in Audia and Rider's (2010) study of the US footwear industry. In this case, plant failure rates were higher in agglomerations, but this effect was weakened and even reversed in agglomerations with locally headquartered plants.

Summing up, the literature on low-tech manufacturing provides many valuable insights into the current transformation and characteristics of these industries. However, this review has identified key shortcomings in the literature that need further research. Firstly, the literature focuses primarily on highly skilled labour, formal education and partly vocational training, while learning-by-doing and learning-by-using processes are overlooked, processes that are vital to industries depending on synthetic knowledge bases. Secondly, and related, the literature does not analyse knowledge relations between low-tech firms and customers over time and the following changes in learning processes in such user-producer relationships. Thus, this points to a need for a stronger learning perspective on low-tech manufacturing. Thirdly, studies of the importance of external relations for firm competitiveness are predominately based on empirical evidence from Europe, thus, there is a shortage of studies analysing this topic in other high wage economies with different institutional set-ups. Fourthly, while capital investment are considered central to the competitiveness of low-tech firms, affordability issues of especially SMEs including financing and search and implementation cost of new machinery are lacking.

Policy implications

As the previous section illustrates, there is a comprehensive literature on various aspects of the development of low-tech manufacturing even though important gaps remain. While the literature review also reveals that policy recommendations are few and often very general, some studies provide detailed advice to policymakers on supporting low-tech manufacturing, as it increasingly moves into

high value-added niches. There is, however, a narrow focus in the low-tech literature on individual policy initiatives and little consideration of interrelations between different policy areas, such as the linkages between labour skills and capital investment. In table 2 we summarise the main challenges faced by low-tech manufacturing and the suggested policy initiatives addressing them as identified in the literature.

Table 2. Challenges of low-tech manufacturing and suggested policy initiatives

Topic	Main challenges	Suggested policy initiatives
Innovation strategies	<ul style="list-style-type: none"> • Identify new high value-added niche markets • Secure continuous incremental improvements of products and production processes 	<ul style="list-style-type: none"> • Support the development of marketing and design capabilities (Hervas-Oliver et al. 2011b) • Establish mechanisms to monitor the needs of low-tech firms (Hirsch-Kreinsen et al. 2006)
Human capital	<ul style="list-style-type: none"> • Shortages of labour with desired skills • Discrepancy between the competencies provided by educational programs and those demanded by low-tech firms • Geographical mismatch between location of low-tech firms and concentration of skilled and especially highly skilled labour 	<ul style="list-style-type: none"> • Attraction and retention of highly skilled labour should not only focus on high-tech manufacturing (Hansen et al. 2014) • Greater attention to improving image and quality of vocational education (Hansen 2010) • Increased focus on functional flexibility and hybrid qualifications in educational programs (Schmierl and Holm-Detlev 2005; Hirsch-Kreinsen et al. 2006) • Public supported training in firms and strengthened relations between educational programs and firms (Hirsch-Kreinsen et al. 2006; Corbett 2008)
Capital investments	<ul style="list-style-type: none"> • Increase productivity in production • Taking informed decisions on investments due to the complexity of advanced machinery 	<ul style="list-style-type: none"> • Encourage investment in new technology (Kumbhakar et al. 2012) • Provide assistance to firms concerning investments in machinery (Hansen 2010) • Policy should put as much focus on diffusion of new technologies as development of them (Robertson and Patel 2005)
R&D investments	<ul style="list-style-type: none"> • Low R&D investments, in particular among SMEs 	<ul style="list-style-type: none"> • Incorporate customer interaction into R&D funding and incentive schemes for low-tech manufacturing (Grimpe and Sofka 2009) • Raise awareness of economic pay-offs from R&D investment in low-tech firms (Kafouros 2008)
Relations outside value chains	<ul style="list-style-type: none"> • Increase relations to relevant knowledge institutions • Absence of external collaborations among many low-tech firms 	<ul style="list-style-type: none"> • Support for non-radical innovation projects of low technological complexity (Radauer and Streicher 2007) • Broaden focus of policy from supporting university-industry research projects to other types of interactions (Schartinger et al. 2002) • Stimulate investment in highly skilled labour (Hervas-Oliver et al. 2011a) • Establish local collective research centres focusing on facilitating technology absorption from the environment in low-tech firms (Spithoven and Knockaert 2012)
Supplier and customer relations	<ul style="list-style-type: none"> • Maintain and develop close relations to customers • Establish relations to research-intensive suppliers 	<ul style="list-style-type: none"> • Incorporate customer interaction into R&D funding and incentive schemes for low-tech manufacturing (Grimpe and Sofka 2009) • Preferential treatment for project consortia including customers (Grimpe and Sofka 2009) • Create intermediate institutions that can facilitate collaborations (Garibaldo and Jacobson 2005) • Support inter-sectional connections (Hirsch-Kreinsen et al. 2006)
Agglomeration	<ul style="list-style-type: none"> • Develop clusters and MAR externalities: local networks, pool of skilled local labour and knowledge spillovers • Develop external networks and secure labour supply for non-clustered low-tech firms 	<ul style="list-style-type: none"> • Develop cluster policies that consider the heterogeneity of cluster firms (Hervas-Oliver et al. 2012) • One size cluster policy does not fit all (Eisingerich et al. 2012) • Support development of external relations for low-tech firms located in the periphery (Hansen and Winther 2011)

While the recommendations provided under the following categories are all indirectly related to low-tech **innovation strategies**, a few suggestions are specifically focusing on this topic. Hervas-Oliver et al. (2011b) point to the importance of supporting development of marketing and design capabilities in order to allow low-tech manufacturing firms to continuously identify and develop new profitable niches, and Hirsch-Kreinsen et al. (2006) emphasise the necessity of constantly monitoring the needs of low-tech firms so policy can co-evolve with changes in innovation strategies.

Regarding **human capital**, and in contrast to the main focus of the literature, it is recommended that the image and quality of vocational education should be enhanced in order to attract and educate students with both academic and practical skills, thus, delivering graduates with hybrid qualifications and a high functional flexibility (Schmierl and Holm-Detlev 2005; Hansen 2010). Further, it is suggested that the shortage of labour with desired skills may be limited through, firstly, on-the-job training of employees (Hirsch-Kreinsen et al. 2006) and, secondly, extending the efforts made to attract highly skilled labour in high-tech industries such as biotech and ICT to low-tech manufacturing (Hansen et al. 2014).

Despite the significant and generally acknowledged importance of **capital investments** for the development of low-tech manufacturing, surprisingly, nearly no policy recommendations are provided on this topic. For instance, no policy measures aimed at increasing machinery affordability or easing implementation are suggested in the low-tech literature. Kumbhakar et al. (2012) simply state that investment in technology should be encouraged due to the effect on productivity, and Robertson and Patel (2005) urge policymakers to give equal attention to the diffusion of new technologies as to the development of them. Finally, Hansen (2010) argue that there is a need for assisting low-tech firms in choices concerning large machinery investments due to the growing sophistication and complexity of advanced production equipment which make it difficult for firm managers to take informed decision.

The size of **R&D investments** is generally limited in low-tech manufacturing, but as pointed out by Kafourous (2008) they are nevertheless highly profitable. This points to the importance of raising awareness of the economic pay-offs from R&D investments in low-tech manufacturing, especially

among SMEs, as research shows that large low-tech firms are increasingly moving into high-tech fields (Robertson and Smith 2008; Mendonça 2009). One suggested policy initiative is to integrate interaction with customers into R&D funding and incentive schemes through preferential treatment of project consortia involving customers, as the combination of R&D investments and customer collaboration increases the innovativeness of low-tech firms (Grimpe and Sofka 2009).

The increasing emphasis of low-tech firms on high value-added niches also implies that establishing **relations outside value chains** to e.g. knowledge institutions become of greater importance. This is particularly challenging for the many low-tech firms, which have no tradition for such collaborations. Radauer and Streicher (2007) suggest that supporting collaborative non-radical innovation projects of low technological complexity is an effective way of initiating collaborations involving such firms. Further recommendations are to broaden the focus of policy concerning university-industry relations from research projects to other types of interactions (Schartinger et al. 2002), and to stimulate investment in highly skilled labour in low-tech firms as this facilitates collaboration (Hervas-Oliver et al. 2011a). Finally, Spithoven and Knockaert (2012) argue that establishing local collective research centres is an efficient way of assisting low-tech firms in absorbing technology from the environment.

Creating close **relations to suppliers and customers**, including suppliers of machinery from high-tech industries, continue to be of high importance for low-tech firms. Although the literature emphasises this point, it is very scarce on concrete policy recommendations. While it is a general recommendation to support inter-sectional connections by e.g. establishing designated intermediate institutions (Garibaldo and Jacobson 2005; Hirsch-Kreinsen et al. 2006), it is not specified in the literature how these institutions should be implemented and organised. However, one concrete policy recommendation is to give preferential treatment to applications for R&D funding support for project consortia that include customers (Grimpe and Sofka 2009).

Finally, leaving the firm-level and focusing on the role of **agglomerations**, Hervas-Oliver et al. (2012) stress the importance of cluster policies that take the specific characteristics of low-tech manufacturing into consideration, e.g. the significant role of practical knowledge in these industries,

while Eisingerich et al. (2012) emphasise that one-size-fits-all cluster policies should be avoided. The importance of developing MAR externalities should, however, not lead policymakers to disregard non-clustered low-tech firms. For these firms, a primary role for policy is to secure a local supply of labour and support the development of extra-regional relations (Hansen and Winther 2011).

In conclusion, the low-tech literature provides few and fragmented policy recommendations with a narrow focus on individual policy initiatives. Moreover, there is limited consideration of the relevant scales for policy intervention. While a number of studies focus on the regional scale, there is generally no reflection on whether this is the relevant scale for policy intervention. It is, however, suggested that coherent policy programmes for manufacturing industries is needed to support low-tech firms in adapting to increasing competition (Bathelt et al. 2011). Thus, more research is needed that focus on the importance of integrating various policy areas such as firm investments, human capital development and firm relations including user-producer interactions, and identifying the relevant scales for policy intervention. As various policy areas may have different relevant scales for intervention, this makes formulations and implementation of coherent manufacturing policy programmes complicated.

Low-tech manufacturing in Danish innovation and regional industrial development policies

Danish manufacturing sector employment has declined considerably in past decades as in most Western European countries (Hansen et al. 2014). The deindustrialisation is a result of increased price competition and outsourcing of production to low-wage countries and the increasing importance of services. However, in terms of manufacturing production, the sector remains important for Danish export, value-added and, still, employment. 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 low-tech manufacturing followed by the wood and furniture industries and the fabricated metal industry. The Danish low-tech manufacturing industries have R&D intensity levels at or below the OECD average of these industries. To exemplify, the basic metal and fabricated metal

industries have R&D intensities less than 0.5%, while they are classified as medium-low-tech industries in the OECD classification (R&D intensity of 1-3%) (OECD 2005). Among the more R&D-intensive industries, manufacturing of machinery is another important Danish specialisation.

Denmark has an uneven economic geography with concentration of growth and jobs in the two main city-regions: the Copenhagen region and the region around the second largest city, Aarhus (Hansen and Winther 2012). The current spatial pattern with two dominant city-regions is markedly different from the pattern of the 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 (Maskell 1986; Jensen-Butler 1992). At the same time, the largest cities in Denmark including Copenhagen suffered severe job losses because of a strong de-industrialisation process in manufacturing industries (Andersen and Winther 2010). Since the early 1990s, however, there has been a resurgence of the large cities in Denmark in terms of growth in jobs. This pattern has not changed after the financial crisis in 2008. Job losses and firm closures have been severe outside the two city-regions while they have been far less affected by the crisis. Still, there continue to be particularly high concentrations of manufacturing jobs in the middle and Western parts of Jutland, but also in large parts of Funen and peripheral parts of Zealand. Thus, there is a clear divide in the location of manufacturing employment with the jobs being predominantly located in the rural parts of Denmark, that is, outside the main urban growth areas (Hansen et al. 2014).

There is a long tradition for industrial and regional policy in Denmark attempting to rebalance the uneven economic geography (Jensen-Butler 1992; The Danish Forest and Nature Agency 2006; The Danish Government 2010; The Danish Nature Agency 2013). With the 2007 local government reform five new Danish regions and six new regional growth forums were introduced to support regional development. The six regional growth forums are: North Jutland Region, Central Denmark Region, Region of Southern Denmark, Region Zealand, Copenhagen Capital Region, and the island of Bornholm that is in all other aspects part of the Copenhagen Capital Region. The growth forums consist of 20

members appointed by the Regional Council and are a mix of local politicians, representatives of business and labour market organisations and knowledge institutions. The growth forums' overall mission is to create optimal conditions for trade and industry to generate regional growth and development. The regions have financial means to support regional development and growth initiatives, and through the regional growth forums they prioritise the European structural funds. The growth forums produce regional industrial development policies on the basis of regional conditions and specialisations, and national growth policies. We have selected the recent regional strategies and their action plans presented by the regional growth forums. Further, we also include the recent National Innovation Strategy as it is the key policy document at the national level.

Table 3. Emphasis in Danish regional and innovation policies

Topic	National innovation strategy	Copenhagen Capital Region	Central Denmark Region	North Denmark Region	Region of Southern Denmark	Region Zealand	Bornholm
Innovation strategies	<ul style="list-style-type: none"> • Focus on challenge-driven innovation 	<ul style="list-style-type: none"> • Science based development • Focus on R&D activities and high-tech firms 	<ul style="list-style-type: none"> • Emphasis on product differentiation (particular in food processing) 	<ul style="list-style-type: none"> • Focus on both science based development and learning-by-doing 	<ul style="list-style-type: none"> • Emphasis on use of R&D and hiring of graduates • Focus on product innovation and integrating design in product development 	<ul style="list-style-type: none"> • Focus on R&D as the main source of innovation • Emphasis on product differentiation 	<ul style="list-style-type: none"> • Focus on using local knowledge
Human capital	<ul style="list-style-type: none"> • Involve private actors in the development of educations • Increase enrolment at universities • Encourage entrepreneurialism 	<ul style="list-style-type: none"> • Attraction and retention of graduates and talents • Vocational training programmes • Encourage entrepreneurialism 	<ul style="list-style-type: none"> • Encourage hiring of graduates in regional firms • Vocational training programmes 	<ul style="list-style-type: none"> • Increase qualifications at all levels, particularly in SMEs to increase knowledge transfer • Encourage entrepreneurialism 	<ul style="list-style-type: none"> • Encourage hiring of graduates • Vocational training programmes 	<ul style="list-style-type: none"> • Focus on qualifications at all levels, mobility and flexibility • Attraction of more graduates • Encourage entrepreneurialism 	<ul style="list-style-type: none"> • Vocational training programmes
Capital investments	N/A	N/A	N/A	N/A	N/A	N/A	N/A
R&D investments	<ul style="list-style-type: none"> • Increase investments in R&D • Strengthen science-base of industries 	<ul style="list-style-type: none"> • Increase R&D investments of regional firms • Strengthen science-base of industries 	<ul style="list-style-type: none"> • Increase R&D investments of regional firms • Combine with learning-by-doing 	<ul style="list-style-type: none"> • Increase R&D investments of regional firms • Combine with learning-by-doing 	<ul style="list-style-type: none"> • Increase R&D investments of regional firms 	<ul style="list-style-type: none"> • Increase R&D investments of regional firms 	N/A
Relations outside value chains	<ul style="list-style-type: none"> • Focus on collaboration projects with knowledge institutions • Initiation of broad 	<ul style="list-style-type: none"> • Support public-private relations around health-care and welfare innovation 	<ul style="list-style-type: none"> • Strengthen public-private partnerships • Focus on collaboration projects 	<ul style="list-style-type: none"> • Support public-private relations around health-care and welfare innovation 	<ul style="list-style-type: none"> • Support public-private relations around health-care and welfare innovation 	<ul style="list-style-type: none"> • Focus on collaboration projects with knowledge institutions 	N/A

	innovation partnerships around key societal challenges	<ul style="list-style-type: none"> • Strengthen links to venture capital 	with knowledge institutions		<ul style="list-style-type: none"> • Focus on collaboration projects with knowledge institutions • Strengthen links to venture capital 		
Supplier and customer relations	N/A	N/A	<ul style="list-style-type: none"> • Strengthen collaboration along value chains 	<ul style="list-style-type: none"> • Strengthen collaboration with customers 	N/A	N/A	N/A
Agglomeration	<ul style="list-style-type: none"> • Focus on clusters 	<ul style="list-style-type: none"> • Focus on regional clusters (mainly high-tech) 	<ul style="list-style-type: none"> • Focus on rural development 	<ul style="list-style-type: none"> • Focus on regional clusters 	<ul style="list-style-type: none"> • Focus on regional clusters • Focus on rural development 	<ul style="list-style-type: none"> • Focus on regional clusters 	<ul style="list-style-type: none"> • Focus on increasing accessibility
Sources	<i>Ministry of Science Innovation and Higher Education (2012)</i>	<i>Copenhagen Capital Region (2011a; 2011b)</i>	<i>Central Denmark Region (2010; 2011)</i>	<i>North Denmark Region (2010a; 2010b)</i>	<i>Region of Southern Denmark (2012a; 2012b)</i>	<i>Region Zealand (2010; 2012)</i>	<i>Bornholms Vækstforum (2011; 2012)</i>

Essential for the regional strategies is that the productivity growth in Denmark was below OECD average in the past decade even in the Copenhagen Capital Region (Danish Enterprise and Construction Authority 2011). The strategies stress that innovation is the key process to increase the productivity level in regional firms and secure future regional competitiveness. Concerning firm **innovation strategies**, the regional strategies are mainly focussing on R&D and science-based development with almost no attention paid to incremental innovation. Two regions, however, also focus on product differentiation (particular in food processing), which fits with the importance for low-tech firms of identifying new high value-added niche markets. Further, only the Region of Southern Denmark prioritises to increase the use of design in product development, which is recognised as highly important to firms in low-tech industries.

With regard to **human capital**, the regions have a strong focus on upgrading labour qualifications across all industries and increase the employment of highly skilled labour to increase the innovativeness of regional firms. This dual string strategy is evident in all regions although the specific local efforts vary between regions. Attention is mainly paid to regional vocational and continued educational programmes directed at the regional labour force including increased focus on private sector involvement and promoting entrepreneurialism. In relation to secure more graduates and highly skilled, efforts are directed at SMEs and attraction of graduates from outside the regions. In the case of Copenhagen Capital Region attraction of foreign labour and expats is emphasised.

Regarding **capital investment** neither the National Innovation Strategy, nor any of the regional strategies and action plans contain any policies or initiatives directed toward capital investment in regional (manufacturing) firms. Hence, no efforts are directed at the implementation of new process technologies supporting e.g. automation of production in low-tech firms. In general, innovation initiatives are directed against product innovation rather than process innovation.

R&D investment has a central position in both national and regional policy documents. Regions focus on increasing R&D investments in regional firms, but two different approaches can be detected. The National Innovation Strategy and the Copenhagen Capital Region have increasing R&D investments

and strong links to science at the top of the agenda while Central Denmark Region and North Denmark Region combine the emphasis on R&D investments with learning-by-doing initiatives. There is no reference in any of the documents to the value of R&D investments in low-tech firms in particular.

Concerning **relations outside value chains**, attention is mainly paid to collaboration between knowledge institutions (universities) and regional firms with a strong attention to health care and welfare technologies as well as high-tech industries. In some regions, however, it is recognised that local food processing industries can benefit from collaboration with regional universities. To exemplify, Region Zealand's action plan emphasises public funded regional organisations that initiate research based collaboration projects between regional knowledge institution and food processing firms.

There is not any specific focus **on relation to suppliers and customers** in the strategies and action plans. Only the two regions that focus on learning-by-doing mention initiatives regarding the value chain and customers. The strategy of Central Denmark Region pays specific attention to the manufacturing sector, recognising the importance of relations along value chains in food processing firms for the global competitiveness of this industry.

Agglomeration economies are present in most strategies and action plans in terms of regional clusters which include for instance the food processing industries, health care and welfare, cleantech, energy, medico and tourism. Cluster mechanisms are, however, not very well defined and the strategies give limited attention to varying needs of individual industry clusters.

In summary, the specific needs and characteristics of low-tech industries are generally neglected in the strategies on industry and innovation in Denmark. This is evident in both the national and regional strategies and their associated action plans. Attention is primarily given to analytical knowledge production as the foundation for innovation while only a few regions mention development of synthetic knowledge production as a strategy to innovate. Even for industries with a mainly synthetic knowledge base (e.g. food processing industries), most regions emphasise analytical linkages to knowledge institutions in their strategies. While the regional growth forums have adjusted their

strategies to regional conditions, the strategies reflect the priorities of the National Innovation Strategy.

Discussion and conclusion

The recent, increasing literature on low-tech manufacturing provides new insights into the changing character of low-tech industries even though important gaps remain, in particular the lack of focus on learning-by-doing and learning-by-using processes as well as the barriers towards implementation of advanced machinery. The labour intensive low-tech firms of yesterday in high-income countries are gradually replaced by low-tech firms focusing on increasing investments in highly skilled labour, advanced machinery and even R&D. Implementation of new technologies, incremental innovation and focus on high value-added niche markets are the key strategies of low-tech firms. This development is supported by knowledge production and exchange in user-producer interactions between low-tech firms and their suppliers and customers drawing on mainly synthetic knowledge bases. It is stressed that MAR externalities and local networks sustains this development.

The literature confirms that out of the seven themes identified two of the themes are especially important. Firstly, capital investments in form of machinery investments have increased considerably in low-tech manufacturing. Multiple studies point to the importance of such investments for the competitiveness of low-tech firms because they have significantly positive impact on labour productivity. However, the growing sophistication of advanced machinery makes it increasingly challenging for low-tech firms to take informed decisions on investments, and changes the firms' demand for labour increasingly towards highly skilled employees.

Secondly, user-producer interactions are fundamental to the competitiveness of low-tech firms and central to low-tech innovation strategies. Multiple contributions highlight the importance of suppliers as a source of new knowledge which would be difficult to obtain elsewhere. Especially suppliers from research-intensive industries are key sources of knowledge for low-tech manufacturing. Concerning linkages to customers, these are of key importance for low-tech firms, as they allow a detailed understanding of the (changing) needs of the market and the development of advanced design

capabilities. Low-tech firms are more market oriented in their knowledge linkages than high-tech firms and the effect of collaboration with customers on innovativeness is significantly higher in low-tech manufacturing. Thus, the role of customers for the innovativeness of low-tech firms is crucial and increasing over time.

The literature on low-tech industries concludes that the sector is still important in many European countries in terms jobs, value-added and exports, but that it is a continuing challenge to adapt new strategies. However, only a limited amount of the studies reviewed give policy recommendations for supporting the development of low-tech industries, recognising the specific characteristics of low-tech. Concerning capital investments, the few recommendations are general with focus on encouraging investment in new technologies, and highlighting that policy should put as much focus on the diffusion of new technologies as the development of them. The policy recommendations in relation to user-producer interactions are more specific. They suggest incorporating customer interaction into R&D funding and incentive schemes for low-tech manufacturing and create intermediate institutions that can facilitate collaborations and support inter-sectoral connections.

While active industrial policies are a political priority in Denmark, the National Innovation Strategy and the regional industrial development policies from the growth forums do not take the specificities of low-tech industries into account in their strategies and action plans. There is a strong policy focus on human capital and upgrading of skills, on collaboration between firms and knowledge institutions and on R&D in manufacturing firms. The former is of course vital to manufacturing in general, including low-tech industries. The latter, however, was not pointed out in the low-tech literature as key to securing the competitiveness of low-tech firms. The policies examined in this paper show a lack of recognition of the specificities of low-tech industries and their current state and competitiveness. There is not any focus on capital investment and the current changes in production in terms of automation and investment in new process technologies. Likewise, the policies have limited recognition of the importance of suppliers and customers for manufacturing firms. Thus, they do not take user-producer interaction into account although it has been a key element in the literature on

innovation in the past 30 years. The understanding of innovation in the policies is dominated by a linear innovation model with a science-based perspective. This is especially evident in the National Innovation Strategy and in the policies of the Copenhagen Capital Region. It is also observable in the other regions, but Central Denmark Region and Northern Denmark Region combine it with a focus on incremental innovations and a learning-by-doing perspective. The focus is, however, mainly on food processing industries, while other significant low-tech industries such as wood, furniture and fabricated metal are not considered at all. In sum, the policies do not consider the specific conditions and requirements of low-tech industries.

Consequently, there is a need to rebalance policies so they reflect the economic importance of low-tech manufacturing and the specificities of these industries. Low-tech manufacturing continues to maintain an important position in many regions in Denmark and elsewhere in Europe. The two regions in Denmark that actually have a slightly broader innovation focus, than the narrow linear science-based perspective, are the regions which are the most shaped by low- and medium-tech industries. It is necessary to deepen and diffuse this perspective. Currently, many low-tech firms do not find the present policy programs relevant as they are often designed to support codified knowledge creation (Hansen 2010), and further, many low-tech firms, especially SMEs, are not even aware of the existence of regional industrial policy (Groth and Winther 2013). If regional policy's aim is to support regional industries, programs should also target low-tech firms and their specific product and product innovation processes. Concrete policy proposals that can support the current transformation of low-tech industries include programmes with less formal a priori documentation of the outcomes, and programmes sustaining long-term relations between suppliers-producers-costumers to enhance learning over time. There also seem to be a need for stronger outreach services by local and regional policymakers to include low-tech firms – in particular SMEs – and schools of vocational education and training in policy programs.

While low-tech manufacturing is not job creating due to the increasing use of automation in production, it can be job preserving and job changing as the transforming character of low-tech

manufacturing requires new job profiles with upgrading of formal qualifications and skills. Thus, the foundations for competitive low-tech industries are also worth the attention of policymakers and the recent emphasis on smart specialisation policies in Europe holds, in fact, the potential for a greater emphasis on this issue. According to the smart specialisation perspective, high-tech sectors should not automatically receive higher prioritisation than traditional industries that use and adapt high-tech products (McCann and Ortega-Argilés 2013). Time will show if this potential change in European regional policy materialises.

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¹ All papers mentioning either “low tech”, “low technology”, “traditional industries”, “traditional manufacturing”, “mature industries” or “mature manufacturing” and at least one of the following keywords in the title or abstract were considered for the analysis: absorptive capacity, agglomeration, capabilities, clusters, collaboration, competition, competitiveness, development, export, growth, human capital, innovation, knowledge, labour, learning, location, network, outsourcing, policy, productivity, proximity, R&D, region, research, skills, technology and venture capital.

² A limitation of this methodology is that we do not include many single-industry case studies; however, the paper is not concerned with differences between low-tech industries. This is nevertheless an important area of future research.

ⁱⁱⁱ I.e. relations that focus on obtaining knowledge or influencing market structures rather than buying or selling products.