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Manufacturing in the Knowledge Economy: Innovation in Low-tech Industries

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Abstract

This chapter examines the role of low-tech manufacturing industries in the knowledge economy. It is argued that low-tech industries continue to be of large economic importance in high-wage countries, as they actively pursue strategies to maintain competitiveness and increase the value added of products and processes. A strong synthetic knowledge base and large investments in machinery and human capital allow low-tech industries to resist the increasing global price competition. This questions the current focus of policymakers on R&D investments and high-tech industries.

Introduction

Recent studies stress the relevance of a broad conceptualization of the knowledge economy which goes beyond the strong, current policy focus on high-tech industries. Today, low-tech industries continue to have a significant role in European manufacturing in terms of employment, value added and export. However, the character and activities of these industries are profoundly changing as they become increasingly knowledge intensive. Thus, innovation processes and knowledge production in manufacturing are much more complex than suggested by the classic division into high-, medium- and low-tech industries. This calls for a rethinking of manufacturing's position in contemporary capitalism and a redefinition of the central categories based on research and development (R&D) intensity that dominates the debate on the knowledge economy.

Our use of the term 'the knowledge economy' refers to an economy where acquisition, creation and utilization of knowledge are the key factors explaining competitive advantage of firms. The increasing speed of knowledge diffusion on a global scale implies that strongholds and favorable positions only exist temporarily. Firms must constantly innovate to maintain profitability. Importantly, this is the case in all types of industries. Thus, this conception of the knowledge economy does not emphasize specific industries, for instance high-tech industries or knowledge intensive business services nor a science-based view on innovation. Neither does it emphasize specific types of knowledge, such as scientific knowledge. Rather, it highlights that the economy in general is becoming more knowledge intensive.

This chapter is organized as follows. We start by introducing the taxonomy of high- and low-tech industries and its rather one-dimensional understanding of innovation. We introduce industrial knowledge bases as an alternative framework for analyzing innovation in low-tech industries. The empirical part of the chapter accounts for the importance of low-tech industries in Europe, analyses manufacturing investments in capital goods and human capital, and relates the investment patterns to low-tech innovation. The final section concludes and considers implications for policymakers.

High- and low-tech industries

The relatively low R&D investment levels in Europe compared to the USA have often been stressed as a main explanation for the former's lower GDP growth and productivity during the 1990s (Sapir et al. 2003; European Commission 2004). The underlying assumption is that the less research-intensive parts of the economy are unable to withstand competition from low-wage countries with increasingly skilled labor forces due to the high European wage levels (Dicken 2011). Therefore, continuous investments in R&D leading to radical innovations are prioritized to achieve long-term economic prosperity. Associated with this is an emphasis on high-tech industries defined by their R&D intensity and subsequently on the large city regions where these industries are concentrated. Thus, non-R&D intensive industries are receiving decreasing attention by policy makers and this will eventually also have significant effects on regions focused mainly on low-tech industries. An important way in which this science-based view of innovation influences policymaking is through industrial classifications based on a linear conception of innovation processes. The most widespread and influential classification system is the one developed by the OECD and Eurostat, which is based on the R&D intensity of different industries. Outcomes of R&D are characterized by significant elements of novelty and scientific or technological progress (OECD 2002), and the R&D intensity is given by 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 classification by the OECD of manufacturing industries that we use below to illustrate the problems of using this taxonomy to understand competitiveness of manufacturing industries.

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) (2.5)
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, 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)	

Source: OECD (2004)

The attractiveness of this taxonomy in a policy context is closely related to its simplicity which makes it very precise and easy to measure (Jacobson and Heanue 2005; Godin 2006), in contrast to other, more elaborated alternatives. For instance, the taxonomy by Pavitt (1984) overcomes this limited view of innovation, as it considers employment of skilled employees, learning-by-doing and learning-by-using. Firms can therefore be classified as high-tech even though the actual R&D intensity is relatively low. Similarly, Bar-El and Felsenstein (1989) consider that an industry's technological intensity depends on the percentage of academic and skilled labor, 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) include similar measures as Pavitt (1984) and Bar-El and Felsenstein (1989), and furthermore stress the importance of a number of other aspects such as organizing capacity and the ability to design solutions through synthesizing different fields of knowledge. They argue that such measures are necessary to describe the full innovativeness of firms and sectors, and that any attempt that rely just one indicator is reductionism; a complex issue such as innovation needs different indicators, which cannot be compiled into one. However, even the more complex measures remain within the framework of defining high- and low-tech industries. We suggest a different perspective focusing on the use of different types of industrial knowledge bases.

Knowledge bases and low-tech innovation

Thus, another way to distinguish innovations is to consider their relation to current level of technology (Fagerberg 2005). A constant improvement of a product or a production process is considered an incremental innovation, as it is not fundamentally different from well-known technologies in the field. A radical innovation, in contrast, is completely different from the current products or processes available on the market. Whether the firms in an industry primarily create incremental or radical innovations depends fundamentally on the characteristics of the industry. In general, this can be termed the *industrial knowledge base* (Asheim and Gertler 2005; Asheim 2007). Asheim and Gertler (2005) distinguish between two main knowledge bases. A key feature of the *analytical knowledge base* is the use of scientific methods and modeling. Codified knowledge is a major input as well as a major output of the knowledge creation process, and links to universities and research institutions are therefore crucial to the innovativeness of firms with analytical knowledge bases. Innovations are often radical, contrary to the predominantly incremental innovations in industries with *synthetic knowledge bases*. The firms in these industries primarily utilize existing knowledge in new product and process developments, and tacit knowledge acquired through learning-by-doing and learning-by-using is therefore central to innovation processes. While links to knowledge institutions can be of importance, especially within the field of applied research, up- and down-stream relations are in particular significant, as innovation projects often revolve around identifying engineering based solutions to technical problems.

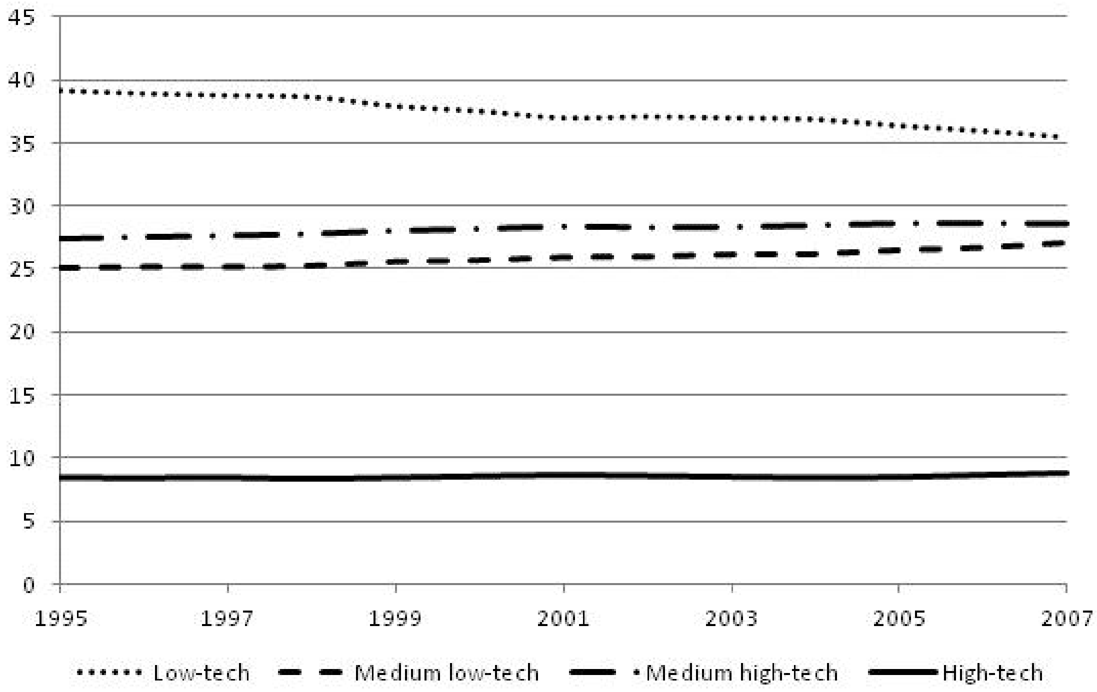
The insight that industries rely on different knowledge bases is important, as it opens for an alternative understanding of knowledge creation and innovation processes than the dominant science based view and the taxonomy of high- and low-tech industries. Recently, interest has increased in the types of capabilities and innovation processes that allow low-tech industries to maintain competitiveness (e.g. Bender and Laestadius 2005; Arundel et al. 2008; Hirsch-Kreinsen 2008; Kirner et al. 2009; Petrou and Daskalopoulou 2009; Hansen 2010). While, on the one hand, some low-tech firms increasingly move into technology intensive product categories (Robertson and Patel 2005; Mendonça 2009), the majority of low-tech firms, on the other hand, rely on a predominantly synthetic knowledge base that allows them to develop customer specific solutions and continuously improve products and production processes. Low-tech firms utilize *transformative capabilities* to convert global knowledge, which is available worldwide, to knowledge that is specific to a certain context, and *configurational capabilities* to synthesize novelties by organizing knowledge, artifacts and actors in new ways through collaborating, (re-)designing and tapping into various types of knowledge pools (Bender and Laestadius 2005). The importance of such capabilities is underlined by recent research which shows that these factors explain firm innovativeness better than R&D investments in all types of manufacturing industries – not just low-tech (Hervas-Oliver et al. 2011).

Thus, there is an increasing recognition that the importance of science-based knowledge production had been exaggerated, and that it is necessary to specifically understand knowledge production in low-tech industries. However, despite this development, there is still very limited knowledge on the investments of low-tech industries in human capital and capital goods. As noted by Smith (2002), such investments are of central importance to the innovative capacity of firms, and the size of these expenditures is considerably larger than R&D investments across industries. In the subsequent sections, we analyze these issues and relate them to low-tech innovation processes, but firstly, we account for the economic importance of low-tech industries in high-wage countries.

Economic importance of low-tech industries

The relevance of analyses of low-tech innovation patterns is evident considering the continuing importance of low-tech industries in Western countries. Non-R&D-intensive industries maintain a high and stable share of manufacturing value added and employment (Kaloudis et al. 2005; Hansen and Winther 2011). Figure 1 illustrates this point. Even though low-tech employment has decreased over the years, these industries continue to account for a larger share of manufacturing employment than the other types of manufacturing. Further, the medium low-tech industries' share of employment has in fact increased over the period from 25.1 % in 1995 to a maximum of 27.0 % in 2007 which is the latest year with available data. The share constituted by high-tech manufacturing remained stable throughout the period, varying only between 8.3 % and 8.8 %. This enduring economic importance of non R&D-intensive industries is also reflected in developments of labor productivity over time. The growth rates of labor productivity in the four different types of industries have been very similar since the millennium in European manufacturing (see Hansen and Winther 2011).

Figure 1. Shares of manufacturing employment (%)



Note: Based on figures for nine European countries with available data throughout the period: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Spain and Sweden

Source: Own calculation, data from OECD's STAN database

This persistence of non-R&D-intensive industries in high-wage countries is remarkable considering the policy emphasis on R&D and high-tech industries. The priority given in Europe to research and high technology is evident through EUREKA, an inter-governmental R&D programme,[1] as well as the EU-wide support programmes which focus on promoting R&D activities and neglect non-research-intensive innovations (Hirsch-Kreinsen 2008). An important factor explaining the continuing competitiveness of these low-tech industries is investment patterns. While low-tech industries – by definition – have low R&D investment levels, they may nevertheless maintain competitiveness through investments in capital goods and human capital.

[1] Full members are 40 European countries as well as the European Union (EU).

Investments in capital goods and human capital

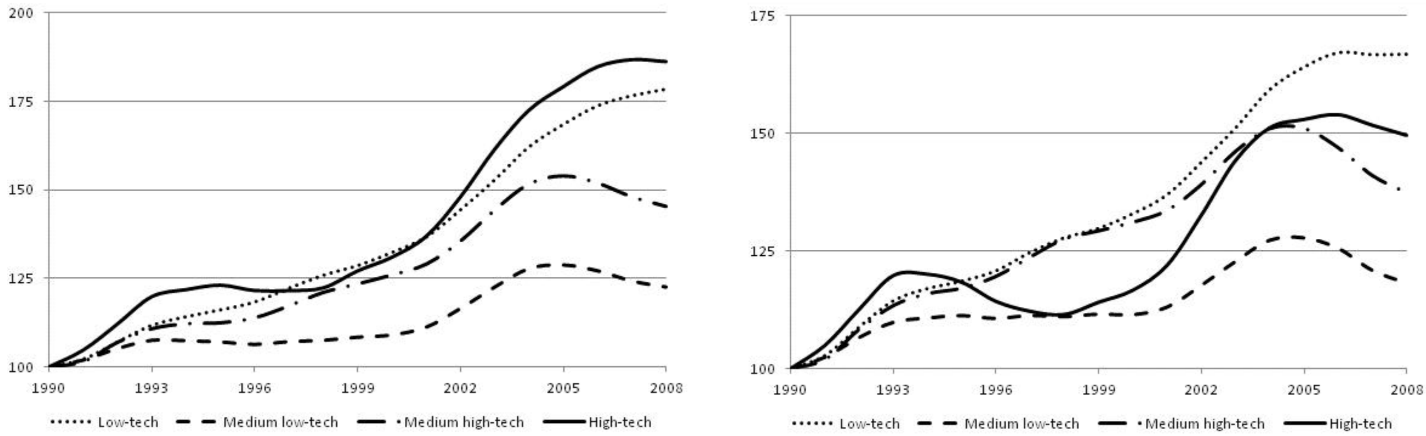
The development of investments patterns in Danish manufacturing highlights the possibility of a route to sustained manufacturing competitiveness which is not primarily depending on R&D investments.[2] The changing composition of Danish manufacturing over time is quite similar to the one described above for a larger sample of countries, even if the share of low-tech manufacturing employment is relatively large in Denmark (38.5 % in 2007 compared with an average of 35.5 % for all nine countries, see also Hansen 2010). Figure 2 presents the development in capital intensity (the capital/labor ratio) for Danish manufacturing industries in the period 1990-2008. Figure 2A includes all types of capital investment – from buildings and machines to software and art. The graph shows that the high-tech industry has the largest growth over the period, but the capital intensity of the low-tech industry increases to nearly the same extent.

Examining the development of capital investments solely in machinery (figure 2B) presents a fairly different picture. Low-tech industries have by far increased machinery investments the most. Further, it is worth noticing that the low-tech industries maintain a stable investment level into the global recession, while the three other types of industries decrease their investments in machinery towards the end of the period.

[2] Such a route is not unique in a European context – see Fagerberg et al. (2009) for an analysis of how the Norwegian economy has remained competitive despite a low R&D investment level.

Figure 2. Capital intensity over time in Danish manufacturing (1990 = index 100)

A) All capital investments *B) Machinery*



Note: To reduce fluctuations, values are calculated based on 3-year averages of investments in the preceding, the actual and the following year. Values for 1990 and 2008 are 2-year averages

Source: Own calculation, data from Statistics Denmark

Capital – and in particular machinery – investments are not the only types of investments of increasing importance to low-tech manufacturing. While many studies point to the role of highly skilled labor for the development of high-tech industries (e.g. Zucker et al. 1998; Murphy and Siedschlag 2011), it is often overlooked that low-tech industries are increasingly investing in human capital. In fact, in a Danish context, the growth in the low-tech industries' use of highly skilled labor is significantly higher than the growth in the three other types of industries (Hansen et al. 2013). No significant distinctions are found between medium low-, medium high- and high-tech industries, emphasizing that human capital is particularly of increasing relevance in low-tech manufacturing. Still, the low-tech industry has a considerably lower percentage of highly skilled labor than the medium high- and high-tech industries (see table 2). However, it should be noted that the share of highly skilled labor is consistently higher in the low-tech industry than in the medium low-tech industry, underlining that there is not a one-to-one relation between industries' R&D investment levels and their use of human capital.

Table 2. Growth in the share of highly skilled labor (1993 = index 100). Brackets indicate absolute shares

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

Note: Highly skilled labor defined as employees with formal education equaling bachelor's degree, master's degree or PhDs, equivalent to ISCED categories 5A and 6 (UNESCO 1997)

Source: Own calculation, data from Statistics Denmark, Hansen et al. (2013)

Qualitative studies of innovation processes in Danish low- and medium low-tech industries confirm that investments in capital goods and human capital are crucial for the competitiveness of these manufacturing firms (Hansen 2010; Hansen and Winther 2011). Naturally, investments in machinery are the most labor saving capital investments as they often aim at increasing automation. Such investments may be of significant importance for the competitiveness of low-tech firms as they decrease the share of firm expenditures constituted by labor costs. While reduced labor costs is by far the most important benefit of such investments, consistent levels of quality, increasing production capacity and optimal use of materials are additional advantages of the growing emphasis on machinery investments in low-tech firms (Groth et al. 2012).

The use of increasingly advanced machinery has considerable consequences for the skill requirements of employees in low-tech firms. Firstly, while low-tech industries have traditionally been major employers of unskilled labor, the accelerating substitution of machinery for labor implies that this is gradually less the case. Secondly, firm managers of low-tech firms note that the processes of selecting new machinery are increasingly challenging and time demanding due to both the complexity of the machines and the number of available models on the market. At the same time, taking the right decisions when acquiring new equipment is also very important due to the substantial financial costs associated with the purchase of many types of sophisticated machinery. Consequently, these processes are highly prioritized by managers of low-tech firms, who therefore hire employees with considerable technological knowledge which can ensure that the right decisions are taken. Thirdly, implementation, operation and maintenance of advanced machinery require increasingly higher skill levels of the employees. In summary, the increasing use of sophisticated machinery is a main driver of the significant upgrading of skills in low-tech manufacturing.

In addition to the close relation between the use of advanced machinery and investments in human capital, highly skilled labor is also of growing importance simply due to the increasing sophistication of product development in low-tech firms. One important role of highly skilled labor in low-tech firms is to facilitate collaborations with high-tech partners. Increasing diversification of low-tech firms into more research intensive fields (Robertson and Patel 2005; Mendonça 2009) is associated with a high frequency of joint innovation projects between high- and low-tech firms where partners bring together analytical and synthetic knowledge (Hansen and Winther 2011). These collaborations are beneficial for both sides as firms relying on either analytical or synthetic knowledge tend to be less innovative than firms that combine the two knowledge bases in their development processes (Jensen et al. 2007), and the projects provide access to competencies and knowledge which are otherwise difficult to acquire (synthetic knowledge for high-tech firms, analytical knowledge for low-tech firms). In these partnerships, low-tech firms typically contribute with knowledge on materials, production processes and engineering techniques. To enter the collaboration, the high-tech firms will often require that the low-tech firms have highly skilled employees working in development positions to ease communication in the project and ensure that work routines are not too dissimilar between the two firms (Hansen 2012). In this way, highly skilled workers are a necessary condition for successful collaborations between high- and low-tech firms.

An example of the benefits of such collaborations is the partnerships between a manufacturer of plastic products and pharmaceutical firms (Hansen and Winther 2011). The lack of plastic-specific knowledge among many pharmaceutical firms offers a possibility for the plastics producer to get involved in collaborative innovation processes on both drug delivery devices and production facilities, most notably clean rooms. Over the last decade, the firm has engaged in a considerable number of such development projects, thus, developing a strongly specialized expertise on plastic molding technology with relevance for the pharmaceutical industry. These collaborations lead to results – such as reduction of production time by 50 % – which are beyond the reach of the firms individually. The plastics firm invests heavily in facilities, education and training that underpin the specialization of the firm, but it is still necessary to collaborate with firms in the pharmaceuticals sector, who are at the forefront of R&D, to achieve successful innovations in these product categories. This exemplifies the mutual benefits to high- and low-tech firms of these collaborations with regard to execution time, knowledge build-up and market access.

Summing up, this section emphasizes that it is a mistake to equal the lack of R&D-intensity in low-tech industries with a lack of knowledge intensity. Increasing investments in advanced production equipment and highly skilled labor are fundamental to the competitiveness of these industries in high-wage countries. However, the changing character of low-tech manufacturing is also resulting in some worrying prospects concerning the position of unskilled labor in an increasingly advanced manufacturing industry. As argued by Christopherson and Clark (2007), while not all industries have a great need for employees with PhD degrees, medium-skilled labor is increasingly becoming a minimum requirement across different types of industries. In this way, the developments that underpin the continuing competitiveness of Western low-tech firms are associated with an increasing employment problem for unskilled labor.

Conclusions

In this chapter we have argued that low- and medium low-tech industries maintain significant economic importance in high-wage countries, but that the character and activities of these industries are profoundly changing. Contrary to the assumptions of much academic and policy work, low- and medium low-tech manufacturing industries continue to be present in Western countries. While the shares of manufacturing employment and value added constituted by low-tech industries have decreased slightly over the recent decades, this is not the case for medium low-tech industries. Consequently, non R&D-intensive industries continue to make up the clear majority of both manufacturing employment and value added in Europe.

This fact stresses that low-tech firms are not passively waiting to be outcompeted by firms from low-cost countries. Instead, they are actively pursuing strategies to maintain competitiveness and increase the value added of products and processes. The innovation strategies of non R&D-intensive firms are founded on inherited capabilities that provide a platform for incremental improvements of products and production processes as well as the customization of products. A strong synthetic knowledge base allows firms to, e.g. change from producing large batches of standardized products to specializing in prototype fabrication.

However, it is equally important to recognize that increasing investments in machinery and human capital are fundamental to the competitiveness of low-tech industries. Low- and medium low-tech firms are in general not particularly threatened by increasing global price competition. Of course, some firms will maintain a focus on cost competition, and not intensify investments in skills and equipment. While the future viability of these firms is highly uncertain, the majority use a variety of means to stay competitive, including investments in sophisticated machinery resulting in reduced labor costs, and increasing employment of highly skilled labor. Thus, framing the conclusion in a positive tone, there is clearly significant potential in advancing the position of low- and medium low-tech manufacturing industries in high-wage countries, which policymakers should pay attention to. This involves, for instance, assisting firms in the increasingly difficult selection process in acquiring sophisticated machinery, or introducing policies towards attraction and retention of highly skilled labor specifically in low-tech industries. In fact, following the argument of Porter (1990), a selective factor disadvantage concerning wages can stimulate a transition towards innovative practices that may secure a long term strong position of Western European low-tech industries.

Based on this analysis, a final question to consider is the relevance of the low-tech/high-tech taxonomy. Certainly, the R&D intensity of industries is an important characteristic, but the emphasis in policymaking on high-tech industries suggests that this taxonomy does more harm than good. There is a need for a broader conception of manufacturing in the knowledge economy, which goes beyond R&D and radical innovations. Thus, more nuanced taxonomies (e.g. Pavitt 1984; Bar-El and Felsenstein 1989; Laestadius et al. 2005; Asheim 2007) that pay attention to, among other things, human capital levels and capital investments have more to offer. Rather than attempting to rank industries according to their knowledge intensity, there is a need for understanding and underlining inter-industrial differences in the types of critical knowledge and the ways this knowledge is sourced. Today, all manufacturing industries in high-wage regions such as Western Europe are knowledge intensive, and this should be reflected in the labels we apply to them. While the institutionalization of the low-tech/high-tech taxonomy in policy circles makes it unlikely that it will be abandoned any time soon, this chapter emphasizes that there is an alternative to this narrow understanding of the knowledge economy.

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