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4 Transformative paths, multi-scalarity of knowledge bases and Industry 4.0

Marco Bellandi, Cristina Chaminade and Monica Plechero

4.1 Introduction

This chapter discusses the role of combinatorial knowledge and its multi-scalarity in shaping the transformation paths of local productive systems (LPSs) that are affected by the gales of contemporary technological change. Specifically, we look at how access to – and the combination of – different knowledge bases at different territorial scales (local/regional, national, international/global) can support different paths of industrial upgrading for LPSs in the face of the challenges posed by Industry 4.0 (I4.0). We adopt the I4.0+ (plus) perspective defined in Chapter 1, which aims to address sustainable development.

Local and regional transformation paths increasingly rely on complex knowledge dynamics (Grillitsch et al., 2018), which require different types of knowledge to inter-relate in order to support some degree of innovativeness in local systems (Asheim et al., 2017; Grillitsch et al., 2017). Such knowledge dynamics refer not only to knowledge that has different degrees of transferability across spaces (tacit vs. codified knowledge), but more crucially involve different knowledge bases: analytic (science-based), synthetic (engineering-based) and symbolic (cultural-based) (Asheim and Coenen, 2005; Asheim and Gertler, 2005).

Traditionally the literature on knowledge bases has argued that synthetic and symbolic knowledge – both with a high tacit content – tends to be accessed only when actors are in close proximity and with limited international interactions (Martin and Moodysson, 2011, 2013). In contrast, analytic knowledge – which has a higher codified content – tends to be accessible at a wider geographical scale. However, recent evidence suggests that synthetic and symbolic knowledge can also be sourced at an international level, which extends the possibility for accessing and combining all knowledge bases at different geographical scales (Martin et al., 2018).

In this chapter, we build on this suggestion and propose a novel conceptual framework that attempts to match different transformative paths with different forms of combinatorial knowledge creation. We assume that matching might involve different knowledge bases that are sourced at all geographical scales, from regional to global. Furthermore, we will discuss how effective sourcing depends on the use of specific mechanisms and on the presence of place-specific conditions (Section 4.2).

This extended framework will be applied to better understand how access to knowledge and any of its combinations can shape alternative models of value creation in LPSs that are embarking on transformative or renewed paths of development in order to take advantage of the opportunities opened up by I4.0. In particular, digital technologies characterize the core of the I4.0 model, and may unlock and enable new value-creation solutions within LPSs that will impact not only on the economic growth of places, but also on their societal development (OCSE, 2016; World Bank, 2017). On the one hand, I4.0 is pushed by the increasing importance of analytical/scientific knowledge supported by digital coding. On the other hand, the outcomes of innovation processes underpinned by I4.0 include an ever-deeper combination of product, service and societal contents. This implies the necessity of accessing both synthetic/engineering and symbolic/cultural knowledge on complex multi-scalar settings (Section 4.3).

In the final section in the chapter, we will discuss these issues in relation to a number of cases studied within the MAKERS project.

4.2 Access and combination of different knowledge bases in the transformative paths of LPSs

4.2.1 Knowledge bases and local path transformation

As already noted, there is a stream in the innovation literature that argues that local/regional path transformation is favoured when different types of knowledge can be accessed, combined and effectively integrated.[1] Combining different types of knowledge is indeed a distinct feature of current innovation processes transforming the nature of a large number of industries (Strambach and Klement, 2012; Grillitsch and Trippl, 2014, Corradini and De Propris, 2015). This is even more so in the context of both disruptive technological challenges brought by Industry 4.0 and when there is a need to pursue sustainable societal as well as environmental goals (Strambach, 2017).[2]

Attending to the degree of codification and the processes of knowledge creation, Asheim and Coenen (2005) and Asheim and Gertler (2005) distinguish between three types of knowledge bases:

- *Analytic knowledge (science-based)* is often created with the application of experiment-based methods. The value is extracted from the application of scientific principles and theoretical modes of learning. Much of its content can be transferred in a codified form (lectures, reports, publications and patents). Often firms rely on collaboration with research organizations for its creation and on research and development (R&D) laboratories for its absorption.

- *Synthetic knowledge (engineering-based)* relies on inductive processes of problem solving. In production contexts, it is associated with the engineering of new results emerging from doing, using and interacting (DUI) forms of learning (Jensen et al., 2007). The value can be extracted by means of socialization and synthesis of the existing knowledge (Herstad et al., 2014).
- *Symbolic knowledge (cultural-based)* concerns cultural contents and aesthetic as well as immaterial values. Its creation relies on a variety of heritage and life notions and images elaborated by means of trained artistic and cultural intuition. The value can be extracted from creativity and contextualized sense making. Whilst it is highly place-specific, as the interpretation of images, design and symbols varies significantly from one location to another, it can also be embedded in artefacts and media communications by means of design and various types of applied and performing arts.

Due to its mostly codified nature, analytical knowledge could be accessed across large geographical distances and, consequently, industries dominated by analytical knowledge bases tend to display a high propensity towards establishing international networks. Synthetic knowledge, meanwhile, combines elements that are tacit and codified in nature, and, as a consequence, such knowledge can be acquired more through local networks and only to a lesser extent through international networks. Finally, symbolic knowledge-creation processes tend to rely significantly on local knowledge networks (Bathelt et al., 2004; Martin, 2011).

When we consider processes of local or regional transformation, should LPSs' access to and ability to combine different knowledge bases be limited, a high risk of path exhaustion if not decline would materialize. On the contrary, when different types of knowledge can be accessed and effectively combined by local actors, this may lead to some forms of path upgrading. Meanwhile, new path creation would require a high degree of combinatorial knowledge, which often implies an extensive use of differentiated knowledge bases as well as complex multi-scalar interactions.[3]

While some of the initial literature on knowledge bases tends to suggest that synthetic and symbolic knowledge will be sourced in local and regional networks while analytical knowledge can be sourced at the international level (Martin and Moodysson 2011, 2013), Martin et al. (2018) suggest that different knowledge bases supporting the processes of transformation of LPSs can be acquired at different scales depending on the needs and capabilities of specific firms. However, they fall short of explaining how this occurs and which mechanisms are more likely to be activated to access the different types of knowledge and at which different geographical scale. This chapter fills this conceptual vacuum.

4.2.2 Multi-scalar mechanisms for knowledge access and combination in local productive systems and knowledge-led transformative paths

A key issue that emerges from the literature that links knowledge bases to transformative paths is that effective combinatorial knowledge processes require local and global spaces to be bridged or connected. Such connections need to be better understood. At the local level, firms and supporting organizations may use a variety of mechanisms to access different knowledge bases (Trippl et al., 2009), such as market mechanisms, networks (e.g. alliances), hierarchies (e.g. via the operations of multi-national corporations) and spill-overs (e.g. mobility). In particular, knowledge is typically exchanged in *markets* when it is embodied in goods or services whose value is potentially easy to measure. Such embodied knowledge is likely to correspond to analytic or codified synthetic types of knowledge. Typical examples would be the use of patents for a new drug development or the acquisition of machinery for a specific engineering process.

Fragments of all types of knowledge may be accessed via *unintended spill-overs* associated with human capital mobility, the monitoring of competitors, or informal single or repeated face-to-face contacts. Spill-overs tend to occur in close geographical proximity, although larger geographical distances are not excluded, for example, through international mobility (Rosenkopf and Almeida, 2003; Song et al., 2003) or temporary geographical proximity (Torre, 2008).

Networks, on the other hand, are based on trust and reciprocity (Powell, 1990). The reciprocal character of network relationships implies that actors have similar or complementary absorptive capacity as well as frequent face-to-face interactions and/or the sharing of habits and collective rules. Networks are a good mechanism for the transmission of know-how and know-who, and, in that respect, they are likely to be used for the collaborative transfer and the absorption of tacit contents prevailing in synthetic and symbolic knowledge. Networks for knowledge creation and innovation can take different forms: R&D contracts, alliances, research consortia, epistemic communities or communities of practice.

Finally, *hierarchies*, which can be inter-firm and intra-firm, are mainly based on power enforcement together with the sharing of private rules, common routines or a history of previous interactions. Those characteristics also reduce institutional distance across space (Martin and Salomon, 2003). By opening subsidiaries in different locations, multi-national corporations (MNCs) can access and absorb tacit and codified synthetic knowledge belonging to different scientific and technological fields that has been accumulated in different countries or regions around the world (Kafouros et al., 2012).

The propensity of firms to use different mechanisms to access distant knowledge will ultimately depend on the availability and transferability of knowledge as well as the capabilities of firms. By availability, we refer to the degree of concentration of that knowledge in specific regions around the world. The sources of highly novel analytic knowledge, highly specialized synthetic knowledge or key symbolic knowledge are sparse and often highly concentrated in specific locations (knowledge hubs). This means that firms located in knowledge hubs have an advantage in terms of access to such knowledge without the need to engage in extra-regional links. However, having access to knowledge is not enough. The ability of the organization to tap into pools of knowledge is strongly related to its absorptive capacity. Transferability is the possibility to transmit and receive knowledge without noise, bias or leaks, and depends on the degree of codification. Hence, availability, absorptive capacity and transferability determine what mechanism firms avail themselves of to access knowledge at different geographical scales.

The question is therefore as follows: at what different geographical scales do the above-mentioned mechanisms help firms and related organizations access different knowledge bases and trigger combinatorial knowledge creation processes enabling local transformations?

We focus our analysis on LPSs (Becattini and Rullani, 1996): these are (relatively) small regions (urban or rural areas, industrial districts, etc.) featuring one or a few productive specializations, which are more or less complementary. The specializations are related to the activity of a cluster of firms and supporting business and public organizations operating in the place. Productive decisions and activities have key roots in local business and socio-cultural and institutional networks.

Table 4.1 provides a schematic summary of the main mechanisms supporting the access of LPSs to different types of knowledge bases that can be leveraged at different geographical scales. The *appropriateness of the mechanisms* and their role for path transformation in LPSs depend on the wealth of knowledge sources in LPSs and the type of proximity that can be used when accessing different knowledge bases.[4]

In *transformative processes*, market mechanisms are used by companies to access internationally available analytic knowledge, for example, through patents (Herstad et al., 2014). However, firms whose innovative processes are driven by the creation and/or the development of new analytic knowledge either cluster in highly innovative hubs around the world or tend to link to key players themselves located in international knowledge hubs. Networking in this case is a preferable mechanism for distant interactions. Firms located in LPSs with strong research infrastructure are also more likely to have high technological capabilities enabling them to actively participate in research networks on a global scale.

Networks and spill-overs facilitating or implying face-to-face interaction are likely to be used intensively for accessing synthetic knowledge at different geographical scales. Networks in general are likely to work better at local or national levels where institutional distance is limited (Martin and Moodysson, 2013; Mattes, 2012). When accessibility to synthetic knowledge is low or networks and spill-overs at the local level fail to provide new inputs for generating value, firms may decide to use the hierarchical channel by opening, for example, a subsidiary abroad (offshoring of R&D) to acquire synthetic knowledge from a distant location (Liu et al., 2013). The MNC might bring in knowledge accumulated from networks with other places that can be reapplied and reused differently in the host location.

On the other hand, symbolic knowledge is highly context-specific and tacit, moving with individuals or being embedded in specific communities (e.g. communities of practice or epistemic communities). Access to symbolic

Table 4.1 Some key mechanisms for firms in LPSs to access different knowledge bases in a multi-scalar setting

Knowledge base / Mechanism	*Markets (within LPS)*	*Markets (beyond LPS)*	*Spill-overs (within LPS)*	*Spill-overs (Beyond LPS)*	*Networks (within LPS)*	*Networks (beyond LPS)*	*Hierarchies (within LPS)*	*Hierarchies (beyond LPS)*
Analytical	Trade (e.g. patents)	Trade (e.g. patents)			R&D collaboration (e.g. research consortium)	Domestic/international R&D collaboration, but some cognitive/ organizational proximity necessary) **(this can be key for knowledge creation**)		
Synthetic	Trade (market technologies/ goods for codified aspects of engineering process)	Trade (market technologies/ goods for codified aspects of engineering process)	Local mobility of human resources and face-to-face interactions	International mobility, temporary geographical proximity	Networks (often informal)	Domestic networks (also informal, but institutional proximity is necessary)	R&D offshoring from MNCs in loco **(this can be key for knowledge renewal)**	International R&D offshoring (e.g. in specialized hubs) **(this can be key for knowledge renewal)**
Symbolic			Local mobility of human resources	National/ international recruitment of skilled labour	Networking within local community (e.g. community of practice)	International communities (e.g. in epistemic communities, some social proximity is necessary) **(this can be key for new sense making)**		

Source: Authors' elaboration.

knowledge is therefore expected to be based on networks and spill-overs. Social proximity, temporary proximity or international mobility can compensate for a lack of geographical proximity (Gertler, 2008; Martin and Moodysson, 2011). This is particularly crucial when there is a need for companies in an LPS either to link to places where new creative processes are taking place or to inject a new sense of interpretation and new intangible values in established cultural contexts.

The framework suggested here helps us to draw connections across the fragmented empirical evidence on the geography of different knowledge bases. In particular, by linking knowledge characteristics, types of proximity and mechanisms of transmission, it is possible to reach a better understanding of how different knowledge types at different geographical scales can *generate value* for LPSs embarking on sustainable and transformative paths.

4.3 Geographical scales of competing models in Industry 4.0 technological transformation

Drawing on the conceptual framework presented in Chapter 1 in this volume, it is possible and desirable to include considerations of social and environmental sustainability within and around the pure technical core of the current digital and science-driven industrial transformation that goes by the name of *Industry 4.0*. Such inclusion leads to an expanded perspective, so-called *Industry 4.0 plus (I4.0+)*, that implies the generation of alternatives to mainstream models of value creation and distribution, which otherwise would seem to respond deterministically to 'natural' efficiency-driven arguments. Such Industry 4.0 efficiency-driven arguments would include the centrality of smart and webbed factories and platforms, the ruling of large and multi-national firms, combining mass-customization of products and a very high intensity of capital in core processes, together with market domination, skill polarization, and the digitally driven deterioration of the citizen's control over choices on local public and common goods.

In contrast, I4.0+ is based on the idea that the new technologies should and could be addressed to help bringing sustainable growth, a wide mobilization of human capabilities, and prosperity within territories and their populations of firms, workers and families, as well as between territories. Specifically, the I4.0+ perspective aims at better understanding alternatives in local and regional industrial development that face the current challenges of social, economic and environmental sustainability in models of value creation and distribution.

4.3.1 Alternative I4.0+ models of value creation and distribution

The alternatives to conventional 'efficiency'-based models concern various aspects. We refer to Bellandi et al. (2018) for a broader discussion, but here we evoke briefly the core contents of the composite solutions supporting I4.0+ models as alternatives to the technocratic and centralistic mainstream:

- *Inter-dependencies around smart networked micro-manufacturing* (SNMM): small factories are able to incorporate new digital-based technologies in production processes led by craft skills and care. Small firms managing such factories access international networks of designers, customers and suppliers. Localized pools of SNMM drive a transformation of LPSs specialized in manufacturing into product-service systems incorporating territorial servitization (Bellandi and Santini, 2019).
- *Digital participation and distributed service provision*: an open and enlarging set of digital-based services would allow a territorial servitization of LPSs, with the latter being strong and non-dependent on large oligopolistic providers. Services here include trade, finance, advertising, labour selection and training, enterprise resource planning and relationship management, collaborative knowledge and innovation networks (De Maggio et al., 2009). They may develop on local platforms where small firms and citizens are granted digital sovereignty, information freedom and open access (Morozov and Bria, 2018). Local counterbalancing power should be inserted within and supported by national and supranational anti-trust actions.
- *Makers and smart skills*: operative well-trained skills are still crucial in key phases of value chains if production digital-based technologies are developed not in substitution, but in support of professional/creative processes (Barzotto and De Propris, 2019). This would allow LPSs to meet customer-specific demand in complex ways and expand SNMM. Examples are the matching of materials of variable quality with multi-purpose tools (I4.0 as well), related quality control, prototypes of new digital-based production processes, etc. (Bettiol and Micelli, 2014).
- *Quadruple-helix governance of projects of sustainable socio-economic development*: integrated productive development and innovation projects involve and connect constellations of actors. They include engaged developmental universities, local/regional networks of SMEs non-captured by oligarchies, anchored MNCs forced to relinquish predatory strategies, and civic society, with its more or less local social networks and supporting social innovation towards a common good for a sustainable life (Aoyama and Parthasarathy, 2016).

The contents of alternative manufacturing models under *I4.0+* suggest innovation processes that could promote transformative paths for LPSs characterized by a networked plurality of firms and organizations and by manufacturing specializations grown out of the previous wave of technological change (Perez, 2009). It is apparent that a wide and coordinated introduction of such contents would imply the access, absorption and creative combination of different types of knowledge. This would be the basis for paths of accentuated upgrading in these systems.

4.3.2 Knowledge bases and multi-scalar mechanisms in I4.0+

We now apply the framework presented in Section 4.2 to the models discussed just above under the *I4.0+* perspective in order to derive general suggestions on the relations between transfer mechanisms and the multi-scalar setting for knowledge access and combination that drive transformations in LPSs. The core of such a model, we would suggest, lies in SNMM solutions.[5] Within and around such core, there is a need for the development of digital participation and distributed service provision; the diffusion of neo-maker competences, combining artisan attitudes and digital skills; and the quadruple-helix governance of projects of sustainable socio-economic development.

Our concern now is to understand what the geographical scale of processes of knowledge access and combination for innovation might be both for the mainstream technocratic and centralistic models leading to cyber-physical production organizations and for the *alternative distributed model* (inspired to *I4.0+*). In particular, we want to investigate under what conditions LPSs characterized by a networked cluster of independent specialized business organizations can pursue processes of innovation incorporating the alternative model, and using this support paths of sustained upgrading and regional transformation (path renewal or even path creation).

Starting from the productive core, the basic feature that the *alternative distributed model* shares with the centralistic efficiency-driven model is the importance of codified knowledge in terms of digital coding and software development underlining the I4.0 technologies or their applications. R&D on new types of coding and new applications to multiple fields of scientific and technological problems obviously relates to efforts to create analytical knowledge. Such efforts are concentrated, though non-exclusively, in few 'hot' high-tech hubs around the word. The results of their efforts may be in principle transmitted in codified form at a distance. However, the successful transfer and acquisition of such results require absorptive capacity; in other words, they necessitate pre-existing digital competences internal to users-firms, either to generate new combinations between incoming knowledge and the knowledge bases already present in the firm or just to adopt new technologies developed elsewhere.

Given the breadth and the speed of the development of new digital technologies, the support of specialized intermediary agents in LPSs is also needed. They are knowledge-intensive business or service (KIBS/KIS) providers that combine parts of the analytical knowledge with the synthetic knowledge related to the features and idiosyncrasies of specific technological, production or organizational fields of firms in the LPS. In certain cases, KIBS/KIS providers also combine significant components of symbolic knowledge, as with design-driven innovation (Cooke and Eriksson, 2011). Such combinatorial services may be more or less standardized or customized to the needs of particular users.

Large firms can easily access I4.0 technologies. With their large demand, they rely on the services of national and international KIBS/KIS providers by means of relational contracts and formal networks. Temporary geographical proximity with such international KIBS/KIS providers by means of resident teams is to be expected during the developmental phases or to resolve unexpected shocks in usage, whereas ordinary maintenance and upgrading can be supported at a distance.

Trying to navigate the technological requirements of I4.0 technologies raises very different questions for non-centralized LPSs aiming at *alternative distributed production models*. Here we see two main challenges. Firstly, the single business organizations (even local entities of MNCs) included in these LPSs ordinarily cannot represent a large demand of service within the portfolio of national or international providers of KIBS/KIS. Secondly, it seems plausible that LPSs addressing alternative models to I4.0 should find their competitive advantage in market fields featured by a continuous stream of differentiation, incremental innovations and decentralized creativity, combining the personalization of products and artisan ingenuity. Here, synthetic and symbolic knowledge have key functions in terms of value creation, together with an increasing degree of codification and automation in various phases of the value chain. A real servitization of the variable and differentiated digital components needed by firms belonging to the core productive specializations of the LPS would need geographical proximity and versatility, and the help of various types of mechanisms, also including spill-overs and informal networks. This is a territorial servitization (Lafuente et al., 2017), whereby local KIBS/KIS work in stable contact with the LPS users (Bellandi and Santini, 2019). On the other hand, if the LPS is not able to express an effective territorial servitization, digital services may be acquired by LPS users in standardized forms by means of market relations. This would be a situation where the alternative distributed model to I4.0 has reduced the chances of success. Large national and international providers of KIBS/KIS may also be involved in LPSs. If there is the possibility to develop digital platforms servicing a critical mass of local users with some specific smart and connectivity-enabling components, then large providers may find it profitable to invest in local entities (R&D outsourcing).

Around the productive core, the 'alternative way' also needs to expand from business organizations and networks to wider society. Neo-makers, local digital sovereignty and quadruple helix methods of governance express a function played by the contexts of out-of-the factory life that is deeper and larger than just consumption and labour supply. It concerns knowledge access, value creation and value distribution. Giacomo Becattini saw this relation between *in-factory* and *out-of-the-factory life* at work in the development of industrial districts. He pointed to the neo-artisan tendencies opening windows of opportunities in many non-centralized LPSs in advanced economies in the second half of the 20th century. 'The ever-changing multiplicity of needs demands an exit of capitalist production from the "factory", and its return to a plenty of "laboratories" within the society, searching for artisanship, customized service, ties with historical-cultural and environmental sources of peculiar experiences' (Becattini and Bellandi, 2006: 86). And in the words of Sebastiano Brusco: 'Both the "in-factory" and "out-factory" spheres contribute directly to shape not only the quality of civil life but also productivity levels and market competitiveness' (Brusco, 1996: 155–156).

This perspective on the societal side extolled the importance of geographical and social proximity. The local contents of synthetic and symbolic knowledge, which are at the core of DUI modes of learning and innovation (Jensen et al., 2007), were also drawing from the experiences of ordinary life. It was acknowledged, nonetheless, that trans-local networks, local agents of versatile integration and local centres of services were also needed in order to link the LPS with the development of scientific and technological frontiers (Becattini and Rullani, 1996).

The effective involvement of the societal side is also key in the definition of distributed non-centralistic approaches to the contemporary digital transformation under the *I4.0+* perspective. The opportunity to combine, at various degrees of breadth and depth, the different knowledge bases is open to more than a few bridging, integrating, gatekeeping business actors. In principle, it may involve a multitude of business, socio-cultural and institutional agents.

What differentiates the capacity of LPSs to innovate and take upgrading paths of transformation is both the effective diffusion of combinatorial competencies and the collective capability to share a vision on path transformation. The vision may be led by the idea of a key role played by the development of new analytic or synthetic knowledge. However, the vision in itself has necessarily high local and non-local symbolic contents, since it requires a creative exploration of the opportunities offered by I4.0, in which new values and new senses for interpreting society are collectively constructed (Rullani and Rullani, 2018).

Furthermore, such a vision should be supported by collective (public and private) investments in specific open and multi-disciplinary platforms for the development of combinatorial capabilities and digitally based innovations. The development of such platforms necessarily rests on analytic/scientific knowledge. Weak combinatorial capabilities would probably force the LPS down towards lower paths of transformation, which might plug the LPS within centralistic routes of I4.0 or more generally force it to become subservient to global logics by feeding its economic resources to global chains of production and consumption (Storper, 2009: 155–156).

4.4 Examples from the MAKERS project

In this section, we present some applications of the framework developed in the previous sections to the interpretation of the geographical scales of knowledge links relevant to path transformation in LPSs under I4.0+ perspectives. Facts and reflections are collected from eight cases discussed within the reports of the MAKERS project (see Chapter 1 of this volume).[6]

We would partition the eight cases into three sub-sets. The first one includes the transformations of the 'paper province' in the Swedish Värmland Region and the Viareggio yachting industry in the Tuscany region (Italy). The second sub-set consists of three textile-based LPSs in Prato (Tuscany), Borås (in western Sweden) and St Gallen, Appenzell and Glarus (in eastern Switzerland). The third sub-set corresponds to the mechatronic LPS in Veneto (Italy), the automation LPS in Värtmanland (Sweden) and the life sciences LPS in Tuscany.

Only the Tuscany life sciences LPS has a strong basis in a metropolitan area (Florence), whereas the eastern Switzerland LPS is confined within a set of relatively small cities and it includes traditionally a related variety of sectors around the decreasing textile specialization. All the other LPSs are in reality industrial districts supported by different types of regional innovation systems.

In what follows, we focus in particular on the cases of the first sub-set highlighted, that is, the traditional medium-tech industries (the pulp and paper industry in Värmland and the yachting industry in Viareggio), and their geographical scales, knowledge bases and path transformation under *I4.0+* perspectives. Cases falling under the other two sub-sets will be discussed more briefly so as to provide some complementary observations at the end of the section.

The pulp and paper industry in Värmland and the yachting industry in Viareggio have developed in the past few decades as the main manufacturing specialization of the respective LPSs, with competitive advantages grounded in the relation between a strong basis of synthetic knowledge and specific locational factors. Both cases are interesting because such locational factors have been turned in the last few decades into a strong source of symbolic knowledge, still combining with local synthetic knowledge, but also attracting the activity of providers of analytic knowledge. Both cases can be taken as examples of alternative I4.0+ models that challenge the narrower definition of I4.0 and allow us to look at the geographical scale and knowledge bases of paths to upgraded transformation.

4.4.1 Combinatorial knowledge bases and multi-scalar mechanisms in the transformation of pulp and paper in Värmland (Sweden)

In this case, the locational factor is represented by the proximity to a large land of forests, an abundance of woods that may be easily treated for pulp extraction, and a tradition of preservation of the natural patrimony. The pulp and paper industry has developed for almost a century, with a strong presence of manufacturing plants and R&D laboratories as part of some large national and international companies, together with a population of specialized SMEs, also including those related to forest works.

Chapter 6 in this volume by Ramirez illustrates the emergence of a transformation path, from the traditional pulp and paper specialization to a more differentiated and analytic knowledge-intensive path, which is called the 'forest-based bio-economy', within a plan promoted by a local cluster organization in the last decade. The enduring basis is a multiplicity of nuclei of manufacturing synthetic knowledge, in dialogue with the synthetic knowledge of forest-related activities. Crucial manufacturing synthetic knowledge is hosted within the larger plants and accessed thanks to networks and spill-overs at the local level or through technologies partly acquired on external markets. The access to analytical knowledge has also been important both for the absorption and the development of some more capital-intensive technologies in pulp processes, and for an environmentally sustainable approach to the large-scale exploitation of wood resources.

The cluster initiative in recent years has tried to promote the shift to an economy specialized in the production of renewable biological resources, also with the support of digital technologies. In this cluster initiative, a critical role seems to be played by the strategic orientation of national and regional innovation systems, investments by MNCs embedded in the local economy and the role played by technological intermediaries. New analytic knowledge is developed thanks to the presence of R&D laboratories of large MNCs firms, and networks with local and national universities are also supportive in this respect.

The cluster management agency, the national innovation agency and the international technological intermediaries have been able to elaborate an integrated vision and strategy that has also pulled a wave of investments from distant headquarters of MNCs. This includes reference to the highly symbolic contents of the 'bio-economy' (a combination of the local forest tradition, the green strategy of the national innovation system and EU programmes). Moreover, it provides an answer to relevant manufacturing problems (e.g. the disposal of industrial waste), with the interaction between traditional synthetic know-how (accessed by local spill-overs, informal networks and hierarchies) and analytic knowledge (accessed by local formal network and the R&D laboratories of large vertically integrated firms that can digitally control all the phases of the production processes). Around the productive core, the cluster initiative includes projects aimed at diffusing digital competences and increasing the capacity of small local ICT services to access the new demand of the forest-based bio-economy (see Ramirez, Chapter 6 in this volume).

All in all, this case shows a virtuous combination of all three knowledge bases, accessed with appropriately different mechanisms at different spatial scales. The LPS seems ready for accomplishing a path transformation that could be seen, if realized, as a case of successful path creation (see Table 4.2).

4.4.2 Combinatorial knowledge bases and multi-scalar mechanisms in the transformation of the luxury yachting industry of Viareggio

In this second case, the locational factor is represented by the fact that the luxury yachting industry of Viareggio is located adjacent to an important Tuscan seaside tourist attraction, around Viareggio and Forte dei Marmi, which is associated with an image of high-quality recreational products and services.

As detailed in Chapter 5 in this volume by Bellandi, De Propris, Santini and Vecciolini, the long-term synthetic knowledge base of the yachting system is artisan know-how in small shipbuilding. The industry has evolved in the last few decades thanks to the international inflow of analytic knowledge that has allowed the introduction of new advanced materials, constructive solutions and

Table 4.2 MAKERS cases: combination of knowledge bases in a multi-scalar setting in the pulp and paper industry in Värmland

	Path creation towards I4.0+: use of combined analytical, synthetic and symbolic knowledge at different geographical levels transforming a paper and pulp specialized LPS into a forest based bio-economy LPS							
	Markets (within LPS)	*Markets (beyond LPS)*	*Spill-overs (within LPS)*	*Spill-overs (beyond LPS)*	*Networks (within LPS)*	*Networks (beyond LPS)*	*Hierarchies (within LPS)*	*Hierarchies (beyond LPS)*
Analytical		Digital technologies in the pulp processes and aimed at sustainable environment			R&D collaboration with large firms; networks with local universities	Networks with national universities		
Synthetic		Market technologies related to synthetic processes	Spill-over from domestic/ international MNCs within pulp industry located in LPS		Interactions at local level between traditional and forest-related activities (mediated by cluster organization)	Bridging role in international networks played by local MNCs and technological intermediaries	R&D offshoring from MNC located in LPS	
Symbolic					Bio-economy concept: shared values at local level (emerging from a cluster initiative)	Bio-economy concept: shared values with national and international stakeholders		

Source: Authors' elaboration on MAKERS cases, www.makers-rise.org.

gadgets in the building of top-end boats for recreational uses. Nowadays, the LPS is specialized in the production of luxury yachts, with highly sophisticated and price-inelastic demand from wealthy people.

Each luxury yacht is almost a unique piece, with unique design, artisanship and sophisticated technology, including solutions absorbing many types of smart and connectivity digital components. Analytical knowledge is accessed in various ways, but a key role is played by the R&D offices of the local shipyards (which correspond to the sectoral headquarters of large national and international companies), by formal networks with research organizations supported by a regional intermediary organization, and by market relations and informal networks with providers of technology at local, national and international levels. However, R&D is mainly aimed at the creation of new symbolic knowledge for improving design rather than at the development of new analytic knowledge. Furthermore, the construction of each yacht is highly demanding in terms of practical learning and creativity that involves a large number of specialized SMEs and artisans. This local core of synthetic knowledge is based on reciprocal spill-overs, formal networks with the shipyards and informal networks with the providers of technology. Small-scale and personalized information and communications technology (ICT) services for the yacht industry are granted by an ICT cluster based in the nearby city of Pisa. Various types of initiatives (local fairs, professional schools, etc.) can involve the local citizens in shaping the destiny of the local industry, even if the growth of neo-maker competences seems quite weak and given that related quadruple-helix projects are not surfacing at the moment. Indeed, the main knowledge input into the LPS comes from the *out-factory* relationships associated with requests and demands raised by wealthy buyers from around the world, as well as by the skippers employed by the ship owners.

While the case of this LPS appears quite unique, the luxury yacht industry may be seen as an exemplification of the extreme personalization and co-production that might characterize top-end and niche industries within the I4.0+ model. The uniqueness of each product, the continuous introduction of new solutions and the adoption of the latest technologies make it difficult to classify what path the LPS is following or can follow. Perhaps it points to a class of paths of 'continuous' renewal, where the creativity that drives personalization may become, in subsequent steps, a source of inspiration for part of the local community to reuse the acquired technologies and develop other related business or civic services. This case is led by the development of symbolic and synthetic knowledge and the absorption of analytic knowledge (see Table 4.3). In particular, symbolic knowledge has strong local roots, but it demands multi-scalar flows and mechanisms of creation and image building, combined with the absorption of new analytic and synthetic knowledge. Perhaps the local structure would not support local path creation, but the multi-scalar actors involved in the delivery of highly sophisticated unique products which are present at a local level could favour new value chains and path creation in other places (see Chapter 5 in this volume).

Table 4.3 MAKERS cases: combination of knowledge bases in a multi-scalar setting in the luxury yachting industry

	Continuous path renewal driven by extreme personalization: development of new symbolic and synthetic knowledge with absorption of analytic knowledge							
	Markets (within LPS)	*Markets (beyond LPS)*	*Spill-overs (within LPS)*	*Spill-overs (beyond LPS)*	*Networks (within LPS)*	*Networks (beyond LPS)*	*Hierarchies (within LPS)*	*Hierarchies (beyond LPS)*
Analytical		Digital technologies advance material, new constructive solutions			Networks with research organizations; networks with providers of technologies (weak R&D)	National and international networks with providers of technologies (weak R&D)		
Synthetic			Local companies reciprocal spill-over		Formal networks within the shipyards; informal networks with providers of technologies			
Symbolic					R&D collaborations for new symbolic/design knowledge	R&D collaborations for new symbolic/design knowledge		

Source: Authors' elaboration on MAKERS cases, www.makers-rise.org.

4.4.3 Other cases from the MAKERS project

Other cases from the MAKERS project help to provide supportive insights and qualifications. The textile cases[7] illustrate *transformation paths based on strong synthetic knowledge* as they face the pressure of contemporary challenges. In all three cases, symbolic knowledge has acquired a key role, although playing partially different functions. In the Prato textile district, the image of creativity and quality of 'Made in Italy' is applied to the synthetic knowledge-based capability to rapidly produce an open and variable range of fabrics in very small batches (with a high degree of personalization and with some help given by digital technologies). Here, symbolic knowledge combines directly into strategies of high personalization of products, and the variety of mechanisms for accessing and absorbing new analytic knowledge is still quite low. In the Borås textile district, a strong governance and innovation system at the regional and national levels has promoted a vision that facilitated the absorption of new global analytic knowledge for the development and production of high-tech textile products. Symbolic knowledge seems to play a role in supporting strategic convergence around a collective strategy of analytic knowledge intensification, helped by multi-scalar mechanisms and integration. In the eastern Switzerland district of embroidery and textile machines, a local system supporting innovation and some civic initiatives, coupled with the presence of local diversified research and manufacturing capabilities, also networked at the national and international scales, help combine the synthetic knowledge basis with the creation of new symbolic and analytic knowledge. In this case, symbolic knowledge apparently plays both roles (i.e. personalization and vision).

Such cases appear to confirm some aspects detected in the first sub-set of cases above. Firstly, the high personalization of products demands the guidance of symbolic knowledge coupled with synthetic knowledge. Secondly, a greater opportunity for radical innovation and path creation seems to demand the guidance of analytic knowledge (accessed on a multi-scalar level) coupled with a subservient but necessary role of symbolic knowledge. In all cases, local access to synthetic knowledge cannot be dispensed in LPSs that seem to evoke alternative *I4.0+* models. However, in the stronger cases, the reproduction and creation of synthetic knowledge is also an open field of local converge of multi-scalar strategies.

Finally, the third sub-set includes cases characterized by the greatest *use of analytic knowledge*.[8] Even for these, while any path of upgraded transformation depends crucially on access to and the adoption of analytic knowledge, the extent and depth of the transformation cannot be related only to the degree of local capabilities related to analytic knowledge. In fact, paths consistent with the alternative I4.0+ model, like in Värtmanland, also critically require access to symbolic knowledge for the creative and absorptive functions and at different geographical scales, beyond the presence of strong local pools of synthetic knowledge.

4.5 Conclusions and further research

The previous discussion linking knowledge bases, multi-scalarity and the transformation of LPSs brings some interesting insights for policies (particularly at the regional level) sustaining LPSs. *Firstly*, regional policies do not necessarily have to ensure that all three knowledge bases (synthetic, analytic and symbolic) are co-located in the same LPS. Contrary to what has often been argued in the literature, firms and other innovative organizations could access different knowledge even from distant locations. Regional policies aiming at strengthening LPSs therefore need to go hand in hand with more general policies supporting the use of mechanisms to access knowledge at other geographical scales. Which mechanisms are more adequate depends strongly on the type of knowledge base, the capabilities of the firms located in the region, and conditions allowing access to knowledge. It also depends on which type of model of path transformation is pursued. In particular, and in relation to the challenges of I4.0, it depends on the prevalent vision (e.g. centralistic and technocratic or non-centralistic and distributed) informing public policies and private strategies. *Secondly*, our framework could help extend policies in terms of considering why two firms in the same industry and with similar levels of innovativeness − one located in a knowledge hub and the other one located in a peripheral region − may have very different configurations.

This chapter has some limitations. Firstly, applying a multi-scalar framework to knowledge bases, which brings in knowledge characteristics and meso- and micro- conditions, requires data that are beyond what is currently available. In the short term, dedicated firm-based surveys or case studies in different LPSs around the world could provide a starting point to conduct empirical analysis based on the proposed framework. Secondly, based on the premise that combinatorial knowledge-creating processes involves the sourcing of knowledge at different geographical scales, our focus has been on theorizing when and how these multi-scalar knowledge-sourcing processes will take place. Admittedly, while the sourcing of knowledge is paramount for innovation, it is only one part of combinatorial knowledge-base processes. Knowledge acquired externally needs to be further processed internally, inside both individual firms and related organizations – and among them – within LPSs. In other words, while this chapter provides some insights as to how different knowledge bases are *sourced* using different mechanisms at different scales, it does not discuss how the firm *combines* them into new knowledge. Other chapters of this book consider this more directly, in so doing looking in depth into some of the MAKERS project cases referred to above.

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Notes

1 See in particular the special issue on knowledge bases in (2017) 93(5) *Economic Geography*.
2 In this latter case, the generation of value often derives from the convergence of unrelated knowledge bases taken from different sectorial contexts and recombined in traditional sectorial specialization (Grillitsch et al., 2017).
3 Various contributions develop concepts and cases around such relations. See Asheim et al. (2011, 2017); Chaminade et al. (2017, 2018); Grillitsch et al. (2017, 2018); Isaksen and Trippl (2016); Manniche et al. (2017); Trippl et al. (2017).
4 Another condition not discussed in this chapter is *appropriability*, which concerns how agents interpret and use the acquired knowledge for extracting value.
5 This also concerns analogous productive solutions outside manufacturing, with precision agriculture, sustainable tourism, creative industries, personalized welfare, etc. (Crespi et al., 2014).
6 A cautionary note is needed: underpinning research on the cases to which we refer was not developed directly for applying and testing of the interpretative framework illustrated here. Therefore, some implications concerning individual cases are speculative. Nonetheless, we are confident about the robustness of the overall comparative panel.
7 See Bellandi et al., Chapter 5 in this volume on Prato; the MAKERS report by Santini and Bellandi (2017), including the case of eastern Switzerland; and Chaminade et al. (2018) on Borås.
8 See Corò and Volpe (Chapter 7 in this volume) on the Veneto mechatronic LPS and the automation LPS in Värtmanland. For the life sciences LPS in Tuscany, See Chapter 6 in this volume.

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5 Industry 4.0

Transforming local productive systems in the Tuscany region

Marco Bellandi, Erica Santini, Claudia Vecciolini and Lisa De Propris

5.1 Introduction

The current wave of technological change is affecting local productive systems of specialised SMEs, such as industrial districts (IDs), which still characterise important parts of the European manufacturing sector. Dominant and quite restricted approaches to Industry 4.0 paint a bleak scenario for such IDs, suggesting that they might be doomed to decline or to becoming dependent on large technological companies. Instead, the more holistic approach that has emerged in the MAKERS project of *Industry 4.0+* (and that is presented in Chapter 1 of this volume) illustrates the opportunities that the new technologies can offer to small-scale firms and systems that rely on them, such as IDs, to embark on transformative paths that recombine embedded specialisation with new technologies.

Indeed, a number of solutions are feasible that see new digital technologies being applied to, combined with, meshed in or integrated with capabilities that are intangible, experience-based and creative in order to generate process and product innovations. In IDs and similar productive systems, such combinations and applications do not just require adaptations internal to single firms in relation to their business models and competence pools; rather, they can trigger a *collective rerouting* that occurs at the system level. This implies the recombination of the productive knowledge within an evolving multiplicity of know-how nuclei with any new incoming knowledge, as well as the transformation of the technological foundations, sectoral specialisations, business networks, supply relations, and embedded social relations and institutional support of the local system.

This chapter will be structured as follows. The starting point of our analysis in Section 5.2 is to present the relevant aspects of Industry 4.0+ in relation to local productive systems. Section 5.3 will discuss the processes of knowledge recombination that can occur in IDs, followed by some case studies taken from the Tuscany region in Italy. Some final remarks will conclude the chapter.

5.2 Industry 4.0+ and local productive systems of SMEs

This section illustrates how Industry 4.0+ can support transformative pathways leading to the upgrading and rerouting of local productive systems of SMEs following the diffusion of the digital technologies linked to the Fourth Industrial Revolution (henceforth FIR technologies) (Schwab, 2016). We will present a framework on the dynamics and dimensions of the collective rerouting that IDs need to engage with in order to benefit from the current technological change. For this, a crucial juncture is a clear understanding of what recombinant knowledge implies in such systems, as it will be more extensively discussed in the next section.

It is now well understood that we are experiencing a wave of new technologies that will completely redraw the techno-economic paradigm underpinning our economy and society; these include biotech, nanotech, neurotech, green and renewables, ICT and mobile tech, 3D, AI, robotics, sensoring and space tech. The impact of these new technologies has been captured so far by the extensive debate on Industry 4.0 that kicked off in Germany in the mid-2010s and that has primarily looked at the application of some of these technologies inside factories to increase efficiency, productivity and flexibility. There is, however, an emergent literature on the opportunities they can offer to redefine business models, value-creation processes and industry supply chains (Porter and Heppelmann, 2014; Hermann et al., 2016).

However, the disruptive change that FIR technologies can trigger is wider and greater than the one underpinning the creation of 'smart factories' only. They can lead to a socio-economic transformation driven by the increasing technological capacity of societies and individuals (Hilbert and López, 2011). The pervasive penetration of digital technologies is changing resource reliance and the organisation of production within and between firms, together with creating new sectors whilst making other become obsolete. The current disruptive technologies are completely altering the nature of and the interface between manufacturing and service sectors, as well as the relationship between buyers and suppliers, and between firms and customers.

Some advanced and emerging economies have already started drawing strategies to support firms, regions and sectors to develop and/or adopt such new technologies to sustain their competitive advantage for longer-term jobs and prosperity (see Chapter 13 in this volume for more details on EU policy responses). Indeed, such transformations and adjustments necessitate a clear and supportive policy vision and tools accompanying the experimental and entrepreneurial spirit of firms.

In this scenario, local manufacturing systems of small and medium-sized enterprises (SMEs) also have to adjust their traditional industrial organisation as well as their knowledge configurations to meet such challenges. Historically, some such systems, like many classical IDs, were able to adapt their internal systemic structure thanks to the propelling role played by their underpinning *cognitive structure* and knowledge bases. The cognitive structure of IDs has tended to rest on: (1) mechanisms of learning and creativity within and among the know-how nuclei of the core manufacturing specialisation; (2) latent local resources of trust and adaptability related to a strong sense of local belonging; (3) small firms thriving as life projects for the local community of entrepreneurs, artisans and skilled workers; and (4) policies supporting the provision of public goods specific to local needs (Becattini, 2004). Because of the above, IDs have evolved by branching out into new but still locally embedded knowledge bases supporting the rerouting of their development (Bellandi et al., 2018).

However, the current disruptive technological transformations require a new and delicate balance between *'smart and digital' competencies,* triggered by the FIR, and *manual and artisan skills*, which remain crucial in customisation and innovation processes. Such integration is not a trivial process. Moreover, the reconfiguration of social regulations and human capital that allows for faster access to data and information, as well as the hybridisation of the systemic embedded know-how, are both reliant on the capabilities of systems' *institutional structure* to accommodate such challenges; the latter include formal and informal norms, as well as policy makers and private stakeholders at the local and national levels.

As contemporary global competition is reshaped at a fast pace by technological change, the diffusion of new technologies may act as a springboard for local manufacturing systems of SMEs to help restore the determinants of their local competitiveness. In the 1980s and 1990s, in the wake of post-Fordism, the mutual adjustment of the cognitive and institutional meso-structures of local SMEs systems, such as many classical IDs, was instrumental in the exploration and exploitation of new knowledge bases related to the diffusion of consolidated technologies (Becattini, 2004). However, the traditional internal mechanisms that generated systems' external economies (ibid.) and supported their incremental adaptation and adaptability are no longer sufficient. Instead, we need to better understand what new mechanisms ought to be in place to accommodate the shocks caused by the incoming radical technological changes. The economic and social sustainability of such systems is not necessarily guaranteed since the auto-reproductive capabilities they rely on are likely to be modified. In fact, the nature and dynamics of districts' external economies will adapt as local systems of SMEs experience new solutions to be competitive and successful in the global markets.

New forms of local external economies are emerging, resulting from the integration of material inputs and digital knowledge along the value chain. How new technological knowledge is combined and recombined with the existing sets of knowledge embedded into local manufacturing systems could determine the creation of a new industrial landscape. Indeed, the ability of local production systems to cope with the technological challenge they face cannot be defined only by firm-level solutions, but rather by solutions that are designed and embraced at the system level within IDs. IDs function systemically on a number of levels: the specialised labour pools they are rooted in, the market and non-market mechanisms of business networking, and the reproduction of the social foundations of entrepreneurship and artisanship. These have to adapt to leverage the benefit of FIR technologies.

There are examples of IDs that have been successful and resilient in evolving markets and technologies thanks to their internal features (Belussi and De

Propris, 2013). They are associated to the so-called 'IDs Mark 3' (Bellandi and De Propris, 2017).[1] These are IDs that have evolved to take on variations in response to changes in technology and markets, including: a) product-service specialisations crossing the borders of different statistical economic sectors; b) heterogeneous populations of networked, specialised and innovative SMEs together with flagship trans-local companies and anchored multi-national enterprises (MNEs); c) insertion in policies of regional and national platforms for continuous learning, research and innovation collaborations, international trans-local services; and d) local social embeddedness of the economic activities rooted in a continuous interpretation of cultural heritage and authenticity within the global flows of persons, information and capital (Bellandi and De Propris, 2017).

In many cases, such variations are only partially developed, while the traditional mechanisms, which cumulate self-reinforcing mechanisms of learning and place-specific organisational models, have become largely unsuitable for the renewal of the sets of embedded knowledge and innovation processes, leading systems to become locked into sub-optimal paths (Arthur, 1994; Antonelli, 1999). Even worse, some are unable to adjust their set of knowledge bases and trigger new learning processes in the presence of disruptive challenges (Martin et al., 2016).

5.3 Processes of knowledge recombination

We have recalled above that in classical (Mark 2) IDs, new knowledge generation begins from the exploitation and exploration of knowledge inputs sourced both internally (i.e. the set of specialised knowledge bases) and externally (i.e. foreign markets, business and institutional partnerships). Here interactions within and across the systems' different knowledge bases enable the transformation and integration of internal and external knowledge inputs through processes of learning by doing-using-interacting, the so-called DUI-mode (Jensen et al., 2007), which are embedded into the idiosyncratic structures of each local system (cognitive and institutional systems).

In IDs relying only on DUI modes, the forces dampening adaptability can be particularly strong when the local system and its main manufacturing sector of specialisation, together with complementary industries and subsidiaries services, have reached the phase of maturity (Menzel and Fornahl, 2009; Hervas-Oliver and Albors-Garrigos, 2014). In fact, at maturity, self-reinforcing mechanisms of learning and innovation tend to take the form of incremental change and repetition that confirm known patterns of success. Furthermore, the institutional structure may become unable to remove barriers and inertia related to rent-seeking and coordination problems (Bailey et al., 2010). In these circumstances, the knowledge set embedded in the system becomes progressively obsolete, unable to hybridise with new incoming knowledge and to renew its configuration. Therefore, recalling the 'rigid specialisation trap' concept introduced by Grabher (1993), it may be argued that beyond some threshold and time, local specialisation weakens local learning and innovation, reducing the capacity to reshape the cognitive and institutional structures in the face of non-gradual changes and putting at risk a long-lasting resilient growth (see Staber, 2001; Boschma, 2005; Frenken et al., 2015).

The challenge for DUI mode systems is how to spot, assess and react to maturity entropic effects and to disruptive external challenges. We would argue that two structural conditions affect knowledge generation in local productive systems of SMEs: the composition of specialised knowledge bases; and crucially the breadth of local business networks (Bellandi et al., 2018). The composition of the specialised knowledge bases maps the sectors embedded in the area and, more specifically, the economic activities belonging to every single local *filière*. On the other hand, the breadth of local business networks captures the distance in the interactions between knowledge bases belonging to the same or different *filières*. These interactions can be established either between closely related knowledge bases when they belong to the same *filière* or between distant knowledge bases when they refer to different *filières*. 'Strong ties' can be argued to feature the sharing of closely related knowledge bases, while 'weak ties' allow contacts between distant knowledge bases (Granovetter, 1985). Business networks with enough breadth to encompass both strong and weak ties promote new knowledge generation thanks to the combination of similar and more distant knowledge bases.

Depending on the wealth and composition of specialised knowledge bases and on the breadth of its local business networks, a local productive system can embark on different types of learning processes. In classical IDs, DUI modes of learning rest preferentially on the combination of similar knowledge bases within the *filière* of the main industry or around it. However, Mark 3 IDs should instead include clusters of different *filières* and open business networks. This is highly relevant in the context of technological change, especially since enabling technologies develop across sectors and *filières*, completely redefining them or creating new sectors and *filières*. Indeed, it has been argued that new production technologies increase cross-sectoral interactions (OECD, 2017), bridge distant knowledge bases, and generate in turn much more radical and disruptive innovations (Corradini and De Propris, 2016).

Given the above considerations, we define four possible types of learning processes taking place in DUI mode-based systems as described in Table 5.1.

QUADRANT 4 **Learning by accumulation**	**QUADRANT 3** **Learning by recombination**
QUADRANT 1 **Learning by substitution**	**QUADRANT 2** **Learning by conversion**

Figure 5.1 Learning processes in local productive systems
Source: Authors' elaboration.

We argue that local productive systems characterised by a small set of specialised knowledge bases and by interactions mostly concentrated within the same *filière* are likely to embark on processes of *learning by substitution* (QUADRANT 1). This is because the joint effect of the limited amount of knowledge bases and of interactions constrained within a *filière* addresses DUI learning processes towards substitution at the margin of obsolete sets of knowledge with newer similar knowledge. They correspond to simple sectorial agglomerations of small firms. *Learning by conversion* (QUADRANT 2) occurs in local productive systems endowed with a few knowledge bases dispersed across multiple *filières*. Examples can be found in IDs still presenting Mark 2 features, for instance, in rural local systems combining agriculture and food processing industries, tourism and craft products. In this case, the DUI mode of learning within closely related knowledge bases is weak. However, interactions with other *filières* may enable the exploration of loosely related knowledge bases, leading to the generation of new knowledge by converting external inputs absorbed through weak ties (an example could be the adoption of off-the-shelf digital solutions, be they hardware or software). *Learning by recombination* (QUADRANT 3) occurs in local productive systems that are endowed with a multitude of knowledge bases and where firms engage in cross-*filière* interactions thanks to extensive and diverse business networks. In Mark 3 IDs, learning by recombination supports the exploitation and exploration of internal and external knowledge sources, leading to novel combinations generated through strong and weak ties. Finally, when the system's endowment of knowledge bases is rich, but the interactions take place mostly within the same *filière*, knowledge generation is limited and occurs through processes of *learning by accumulation* (QUADRANT 4). This type is consistent with classical (Mark 2) IDs that tend to be characterised by highly specialised and developed industrial structures, in which the main value chain has spawned into a multiplicity of secondary economic activities underpinned by related knowledge bases. Strong ties across such closely related knowledge bases support learning processes based on the DUI mode, leading at best to the incremental adaptations of the existing composition of knowledge bases.

5.4 Cases

The conceptual framework presented so far has been applied to analyse three contemporary cases of localised industry in Tuscany (Italy), specifically the textile production system in the Prato district, the yachting production system in Viareggio and the houseware production system on the outskirts of the city of Pistoia. The empirical evidence analysed in these case studies results from qualitative data and information collected via semi-structured questionnaires to firms, as well as to local institutional stakeholders between 2017 and 2018, until theoretical saturation is reached (O'Reilly and Parker, 2013).[2]

5.4.1 The Larciano system of plastic products, household and sanitary goods and toilet accessories

The hostile geography of the Larciano area in the hilly Tuscan countryside makes it difficult to accommodate large-scale production. Nevertheless, this territory hosts a significant agglomeration of SMEs specialised in low-value plastic products, such as brooms, buckets and toilet accessories, and, according to the ISTAT 2011 Census data, this industry employs around 29% of the local workforce.

Historically, this system was specialised in the production of brooms, taking advantage of the easy availability of the necessary natural resources in the area, in particular wood and straw. In the mid-twentieth century, a process of local division of labour led some local small firms to specialise in the production of components of the final products (e.g. the handle and bassine broom). However, this process of local division of labour did not go very far, involving only a small number of firms and leaving only a small set of specialised knowledge bases detectable in the system. The local division of labour remained incomplete and did not lead to the emergence of complementary know-how nuclei, such as those related to mechanical tools.

At the end of the 1990s, firms started exploring plastic materials to replace wood and broomcorn. The entrepreneurial leadership of some more structured firms and the involvement of informal networks of firms producing plastic vases for a nearby flowers industry were enough to adjust firms' production processes and the system's organisational model. The transformation required investments in new machineries and greater vertical integration of the production process to take advantage of economies of scale. Thanks to these adjustments, the local production system has grown since then and has been able to survive the long recession that Italy experienced following the 2008 economic crisis.

However, it now faces another wave of technological shocks that will again test the knowledge structure of the system, posing threats but maybe offering some opportunities as well. Industry 4.0+ has the potential to introduce new materials as fossil fuel-based plastic is somewhat decommissioned, digitalisation might force further investments to upgrade the automation of the production process or, again, digitalisation might overturn the whole industry by introducing new cleaning devices.

Some of these challenges are already discussed by local businesses, as the following quote testifies:

> Firm A asked me to start a micro-scale production of buckets with specific characteristics. So, I started to explore various solutions opened up recently with the newest technologies. We do not have a R&D department, so we started some collaborations with local universities and local consultants, investing a large amount of money into the project. We discovered that the 3D printing is neither cheap nor easy to apply in every kind of production. Large investments are needed to adapt the 3D printer to the

> specific production process we need to make buckets. We also need to train workers. We cannot continue to invest. As first-mover, the returns on such an investment are clearly in the long term and we cannot afford the risk. We are not a large firm, and therefore we decided to wait. (Firm in the plastic production system of Larciano)

As already mentioned, FIR technologies are redefining the sources of scale economies and, at the same time, are allowing efficiency to occur at low scale. This should offer an opportunity to production systems like Larciano that can detect the advantages of new technologies in terms of market experimentation and attempt to embrace change through *some* weak ties beyond the *filière*. However, in the case of Larciano, firm-level capabilities force firms to be imitators rather than innovators. At the same time, the thinness of local knowledge bases reduces the interactions across *filières* and the possibilities for recombinant solutions under collective and systemic learning processes. In this case, the rerouting of the local productive system would need a place-based policy supporting investments that trigger a more robust transition from *learning by substitution* to *learning by conversion* processes.

5.4.2 The Prato textile district

The textile industry has a long history in the city of Prato, dating back to the Middle Ages and extending to a set of other contiguous towns. Before the Second World War, until the post-war recovery period, the district was characterised by two parallel circuits of firms: a core of vertically integrated firms producing few types of carded woollen fabrics, at a large scale, for national and international markets; and a secondary circuit made of small craft producers. In the 1950s, the introduction of other fibres besides wool and of new finishing processes allowed the district to widen its range of products and the development of a system of phase specialised SMEs within the textile *filière* (Dei Ottati, 2003). This system also expanded into a range of complementary *filières*, such as textile machinery or tools and dyes for the textile industry. By the 1990s, the Prato district had peaked and since then it has experienced a slow but steady reduction in terms of firms, employees and production capacity. The rate of shrinkage accelerated after 2002 and 2012 (Dei Ottati, 2018).

The cumulative spawning of knowledge and the continuous integration of new competencies in the local textile *filière* has followed a DUI mode based on the multiplicity of local knowledge bases within and around the main textile *filière*, benefiting from an active and committed institutional support. However, the limited interactions between the textile and other *filières* did not allow the activation of mechanisms of learning by recombination and limited the chances of rerouting the local system to new pathways.

Today, a new knowledge base is surfacing around digital technology services. Santini and Bellandi (2018) found that some manufacturing firms have started combining their specialised manufacturing competences with knowledge related to digital services by means of both internal experimentation and external relations (e.g. with universities and private research institutes). However, a large number of the traditional leading firms seem unable to extend their business networks in order to take advantage of these new competences and to explore radically new processes and markets. This means that the system seems quite unable to explore new pathways and reroute its specialisation. Such rerouting would require changes in skills, capital, organisation and of course technologies, but there is not a shared collective vision on strategies of investments. It is probable that any attempt at rerouting will be a stop-start process. The required transformative changes are stalled not only by a lack of breadth in business networks, but also by a lack of institutional coordination, if not by positive resistance to change. It also has to be considered that the possibility for and strength of collective and public actions in the Prato ID have weakened due to the emergence of an adjacent cluster of Chinese textile producers over the last decade. Various problems of social co-existence and economic legality have surfaced; positive linkages between the two systems have not developed yet (Dei Ottati, 2018).

We would argue therefore that two trajectories appear possible for the Prato ID. The first trajectory sees the system remaining locked in the traditional DUI mode of innovation, with reliance on *learning processes by accumulation* within the local *filière* supported by the integration of digital applications in the knowledge bases related to textiles. Along the second trajectory, the resistance to change in many segments of the local *filière* could lock the district into a hardly sustainable condition of *learning by substitution*. This would prevent any transformative change of the local networks, leading to a reduction in the multiplicity of knowledge bases and the continuous shrinkage of the local textile *filière*, until its natural demise.

The Prato textiles district therefore faces the challenges of Industry 4.0+ standing at an historical juncture. Although the first trajectory is desirable and possible, the second one is more likely, although painfully unattractive, due to the observed internal resistance to change, an inability to leverage emerging knowledge bases for renewal, and a fractured socio-cultural fabric.

5.4.3 The Viareggio system of yachting production

The maritime tradition of Viareggio dates back to the fifteenth century, when its coast became a strategic seaport to control the commercial flows in the Tyrrhenian Sea. Supported by the long-standing tradition as fishers and seamen, shipping production in Viareggio took off in the nineteenth century with the production of small ships and, later in the century, of cargo ships and of 30- to 40-metre schooners, mostly used for fishing and commercial purposes. Around the mid-twentieth century, the main shipyards started to produce recreational boats, in the wake of Viareggio's increasing recognition as a popular seaside resort and tourism system. In the 1960s, the introduction of fibreglass in shipbuilding marked a turning point in the traditional meaning associated with the production and utilisation of boats. On the supply side, fibreglass profoundly affected the structure of the shipbuilding supply chain, making a number of traditional activities vanish, especially those that specialised in woodworking, and giving value to the niches of high-quality production that resisted the change. Furthermore, driven by an increasing demand for leisure boats, over the course of the following decades, Viareggio expanded the local shipbuilding supply chain and became a world leader in the production of luxury yachts. Since the 2008 international economic crisis, the Viareggio yachting system has specialised in the production of luxury mega-yachts over 50 metres (accounting for 25% of global production, according to IRPET data), while reducing the production of mid-size yachts. In 2011, the yachting industry absorbed around 25% of the manufacturing employment in the Viareggio area (identified through ISTAT Local Labour Market Areas: ISTAT 2011 Census data).

Today, the Viareggio yachting system organises and coordinates (particularly through the shipyards) a web of suppliers for the fitting of mega-yachts. Shipyards are responsible for design and planning, services, control and assistance, while production is sub-contracted to a rich network of suppliers, including furniture makers, upholsterers, marble producers, suppliers of technological appliances, window fitters, etc. Manufacturing activities are supported by a constellation of services, comprising business services (e.g. training, marketing, legal and certification), maritime and port services. Considering that the building of a yacht requires about 600 suppliers and pulls together up to 70 different competences, we can think of the yachting system as a platform bringing together multiple *filières*. In addition to the first-tier shipbuilding *filière* specialised only in yachting production (e.g. the construction of external structures), we observe a plurality of other *filières*, concurring to the production of each single component for the internal fitting of the yacht-final product, such as those of production of lighting systems, mechanical and engineering firms. Each *filière* can be considered as a sector per se, being endowed with a multiplicity of specialised knowledge bases all aimed at producing individually recognisable products (e.g. appliances, furnishings, upholstery and lighting systems). The multiplicity of knowledge bases and of cross-*filière* interactions favours *learning processes by recombination*, resulting from knowledge sharing through both strong and weak ties. In this regard, the characteristic of the yachting cluster as a platform of *filières* makes it a suitable network structure and composition for the diffusion of FIR technologies and the adoption of an Industry 4.0+ rationale (with a new business model and new products). The multi-sectoral firms also producing components for the yachting system in fact make considerable use of FIR technologies and are applying them to different supply chains, including yachting itself.

5.5 Conclusions

The shift to new paths characterised by the extension of DUI modes of learning to cross-sectoral relations requires large technological and competence investments, and implies radical organisational changes. They are nevertheless at the core of the systemic rerouting to new paths of development and models of local productive systems of SMEs, such as the Mark 3 IDs. In this regard, SMEs face huge constraints, as they require a financial system and local incentive strategies able to sustain such experimental activities. Nonetheless, this systemic reaction would enable the strengthening of diffused creativity and entrepreneurship in the area, repairing the cooperative nexus necessary for a renewed local division of labour. The hybridisation of systemic embedded know-how would allow the system of SMEs to experience new solutions and rethink their product, their processes and their identity in the global markets, driving through new development paths along an Industry 4.0+ direction.

Fruitful rerouting dynamics should be supported by wide-ranging and robust collective and public actions by institutional bodies, addressing productive development at local/regional, national and international (e.g. EU) scales. For example, radical changes to the education and training system would be desirable, as a greater need for multi-disciplinary approaches to learning is becoming necessary in order to face local and global challenges. A new vision for forming human capital as well as increasing public and private investment would reduce competence constraints and skills shortages, as well as reducing the resistance to technological change at the local level. Awareness of the technological opportunities would curb rent-seeking activities and support sharing of successful experiences in terms of exploration, access, adoption and variation of new technologies and markets, with related variations in business models and networks. Eventually, the sharing of successful cases and good practices will help activate imitation processes and reduce the sense of mistrust that many local manufacturing systems of SMEs have experienced over the last decade, as technological change has occurred alongside upheaval in the social, economic and environmental spheres.

Notes

1 The 'classical IDs' that followed successful paths of local development in the second half of the last century can be seen as Mark 2, while the historical IDs of the first Industrial Revolution would be Mark 1 (Bellandi and De Propris, 2017).

2 See Santini et al. (2018) for more details.

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6 Sustainable manufacturing

Creating a regional forest-based bio-economy

Paulina Ramirez

6.1 Introduction

How regions develop environmentally sustainable new growth paths represents an increasingly urgent challenge for both policy makers and academics interested in sustainable regional renewal. The concern for sustainability comes in the context of increasing perceptions of the scale of contemporary environmental degradation and is leading to growing pressures for changes to existing socio-technical systems as a way of addressing this pressing societal challenge (Geels 2011; Coenen et al. 2015). However, the emergence and diffusion of new socio-technological systems is a complex and long-term process involving significant changes to existing scientific knowledge and technologies, user practices and markets, as well as societal institutions (Geels 2004, 2011). These systemic transitions usually require a re-alignment of multiple technical and social elements in new configurations that are often contested as they can undermine powerful vested interests (Geels 2011; Boshma et al. 2017). Moreover, it is argued that transitions towards sustainable socio-technical systems require purposive action (Smith et al. 2005 in Geels 2011) in the sense that they are the result of policies that consciously address the need for environmental sustainability. Given these conditions, the dynamics of systemic transitions towards green regional economies will differ significantly from the evolutionary processes of regional renewal within existing socio-technical systems discussed in much of the evolutionary economic geography literature (Boschma 2017), which focus on the nature and diversity of local technologies and capabilities, knowledge spill-overs and entrepreneurial responses to new technological and market opportunities.

This chapter describes and analyses initial efforts to establish a new regional growth path based on the transition of Sweden's Värmland Region from a socio-technical system based on the traditional manufacture of pulp and paper towards a forest-based bio-economy. Given the complexity and multitude of factors that influence the regional transition of socio-technical systems, the study of the dynamics of change in one region can help us gain an understanding of the factors and relationships that promote or hinder systemic change. The account highlights the importance of place-specific dynamics of transition processes such as the existence of a natural resource with the potential to become a new source of a renewable biological raw material (in this case the forest); new regional visions and policies; the role of the locality for market formation; and the role of local formal and informal institutions in the emergence and transition towards new regional socio-technical systems. The main focus of the chapter is on the role of agency and new policy initiatives strongly influenced by the need to address major societal challenges such as climate change on processes of regional diversification. The analysis adopts a multi-scalar perspective because many of the key players in Värmland's regional economy are subsidiaries of multi-national corporations (MNCs) or part of their global value chains (GVCs) and global innovation networks (GINs) and because transitions of socio-technological systemic tend to be global in nature, though with important national and regional manifestations.

The chapter is structured as follows: Section 6.2 brings together insights from the literatures on evolutionary economic geography and transitions to discuss changes in socio-economic systems with a focus on environmental sustainability. In Section 6.3 the methodology of the study is presented. Section 6.4 describes and analyses processes of transition towards a sustainable forest-based bio-economy. Section 6.5 discusses the role of agency and the multi-scalar nature of regional transitions to new socio-technical systems. Section 6.6 concludes the discussion.

6.2 Regional transitions towards sustainable socio-technical systems

Evolutionary interpretations of regional development and diversification have emphasised the importance of local knowledge given the path-dependent nature of learning and technological change (Immarino 2005; Castaldi et al. 2015) and much attention has focused on the nature and degree of technological diversity of local knowledge and capabilities which are seen to condition the type of new activities that will be able to develop (Frenken et al. 2007; Nefket et al. 2011; Boschma et al. 2017). In these accounts, novelty is analysed in relation to the existing knowledge base and capabilities of a region, and the main mechanism for local diversification are knowledge spill-overs between industrial sectors (Asheim et al. 2011), whilst the main drivers of innovation and regional renewal are profit-driven firms incentivised by new technological and market opportunities. As argued by Boschma et al. (2017), the focus of recent studies on regional renewal has been on the enabling conditions embodied in regional capabilities, with less attention having been paid to factors that constrain the development of new growth paths and the role of agency in overcoming such obstacles.

Whilst these accounts of the dynamics of regional diversification based on new combinations of previously unconnected technologies (which diffuse through regional economies on the basis of spill-overs – see Castaldi et al. 2015; Boschma et al. 2017) can explain radical and incremental innovation within existing socio-technical systems (Geels 2004), they do not capture the complexities, obstacles and tensions associated with systemic changes of globally dominant techno-economic and social systems. Socio-technical-systems transitions involve not only new technologies but also changes in markets and user practices, as well as institutions (e.g. environmental standards and practices) which are often contested.

It is argued that, in general, private firms have limited incentives to drive sustainability transitions because the goal is related to a collective good (sustainability) associated with numerous instances of market failure (Geels 2011). Moreover, the industries where sustainability transitions are most needed (e.g. transport and energy) tend to be dominated by large MNCs that possess complementary assets (Teece 1986, Rothaermel 2001) (such as specialised manufacturing capabilities and large-scale test trials) that give incumbents a strong position in relation to the entrepreneurial firms that tend to be the first to develop environmental innovations. Therefore, the involvement of incumbent firms that are still embedded in current socio-technical systems in processes of systems transition to a green economy usually requires significant strategic reorientation on their part (Geels 2011). From a regional development perspective, successful transitions towards sustainable local economies therefore require what Coe and Yeung (2015) refer to as a *strategic coupling* between local strategies of regional diversification and the strategic needs of MNCs and their GVCs. This process of strategic coupling has three important characteristics: (i) it is strategic in that it needs intentional and active intervention on the part of both regional authorities and the MNCs active in the region to occur; (ii) it is time-space contingent and is therefore a temporary coalition between local and non-local actors; and (iii) actors from different spatial scales interact (Coe and Yeung 2015). The ability to align regional diversification strategies with those of MNCs is not automatic or always successful (Coe et al. 2004; Dunning and Lundan 2008; Coe and Yeung 2015).

The above discussion suggest that in order to understand processes of regional transitions in line with new, environmentally sustainable, socio-technical systems, the role of agency (including, for example, the collective action by firms and the actions of policy makers) and policy needs to be incorporated into the analysis (Neffke et al. 2016; Boschma 2017; Boschma et al. 2017). The literature suggests that in the case of regional diversification based on the transformation of socio-technical transformation, new entrants such as spin-offs and to a lesser extent diversifying firms will be the key agents of change and the formation of new industries (Neffke et al. 2016; Boschma et al. 2017). However, it is accepted that regional governments can also play an important role as agents of regional transitions by lobbying for the creation of new supporting institutions at the national and global levels. Moreover, when new socio-technical systems are close to the existing knowledge base of a locality, a region can provide a supporting institutional structure for change.

Given that the development of socio-technical transitions are global in nature and scale, especially transitions related to climate change, a multi-scalar perspective that takes into account how global and national processes impact on regional diversification is necessary.

6.3 Methodology

The case study is written following the tradition of 'appreciative theorizing' (Nelson and Winter 1982; Nelson 1994), a theory-building approach widely used in innovation studies and evolutionary theories of innovation and organisational change that concentrates the analysis on the role of actors, relationships and processes that lead to qualitative transformation. Data for the study was collected from 15 semi-structured interviews with representatives from six firms located in the cluster organisation Paper Province (PP) (three MNCs and three SMEs) and nine representatives from the national and regional policy-making system. Interviews took place in 2016, three years after PP won the Vinnväxt competition, and therefore focus on the initial stages of the process of regional diversification and transition.

6.4 Värmland Region's transition towards a sustainable forest-based bio-economy

A structural transition towards a regional bio-economy involves underlying changes in a local economy so that renewable biological resources such as crops, forests, fish, animals and micro-organisms replace fossil fuels and become a major source of raw material for production. In the case of forestry, the biological resource is lignin, a wood component produced as by-product (or waste material) of pulp production, which can potentially be refined into new environmentally friendly fuels, chemicals and lightweight materials (e.g. bio-based household products, composite materials, pharmaceuticals, paper and textiles) (Formas 2012). Lignin has been described as a new 'green gold' because of its potential to replace fossil fuel as a source of energy as well as raw materials. However, many of the technologies related to the bio-economy are still very new to the industrial sector and society. In that sense, the bio-economy represents a new socio-technical system requiring the development of new forms of production and new firms, new markets and changes in user practices as well as new institutions.

The Värmland Region of Sweden has a long history of industrial development based on the forest industry, above all pulp and paper, and deep knowledge of the process technologies underlying these two sectors. At the time that the study took place, there were some 200 companies dedicated to the pulp and paper industry in the region that covered the whole paper and pulp value chain, including companies that manage the forest, paper and pulp mills, all major national and international machine and equipment suppliers, technology and engineering management consultancy firms and other specialised service firms. The majority of the large mills and supplier firms located in the region are the local affiliates of leading global MNCs in the pulp, paper and forest-based industries, and a number of them are also key players in the development of the new technologies used in the industry worldwide. Most of the MNCs located in the region have a long history in the area (in some cases 50–100 years) and are therefore a critical part of the knowledge and competence base of the region. At the same time, these local MNC affiliates are also embedded in the global knowledge systems of their parent firms, which in most cases are headquartered outside the region and often outside Sweden. As well as the large MNCs, the region also hosts many dynamic small and medium-sized enterprises (SMEs). Some of these are stand-alone firms which export and deliver services to international markets, while others mainly supply services and components to the local affiliates of MNCs and are therefore part of the global innovation and production networks of these global firms. The region hosts the University of Karlstad. Whilst the University has played a role in local industrial development, in general academic researchers working in the technological and business fields relevant to local industrial development are few and isolated. Links between the university and local firms do exist, but they tend to be ad hoc and mainly focused on a few PhD placements.

The region also hosts a cluster organisation – PP – established in the late 1990s when concerns about the impact of the decline of the paper and pulp industries in the region motivated the municipality of Karlstad along with other public and private regional actors to establish a cluster organisation. PP was later reorganised into a business association (though it is still mainly a publicly funded organisation) and today has more than 100 member companies. The Management Board of PP includes representatives from the large MNCs as well as SMEs, the regional government of Värmland, the municipal government of Karlstad (which is meant to represent the wider community of the region), the University of Karlstad, as well as a RISE centre (RISE is a network of Research and Technology Organisations, wholly or partly owned by the Swedish state, which perform industrial research and innovation). The regional strategy of PP has been strongly influenced by the leading MNC affiliates operating in the region which are active participants of the Management Board of PP as well as by the Värmland regional government. It is important to note that PP with the support of the Värmland regional government has been the main driving force for the strategic regional transition towards a forest-based bio-economy.

6.4.1 The creation of new regional growth paths

The initial process of transition towards a regional bio-economy can be traced back to the mid- to late 2000s, when the Värmland regional government began to push industry cluster organisations such as PP to adopt a more strategic role in regional industrial development. A number of important initiatives associated with issues of sustainability and innovation were taken by PP in the early 2000s. Examples include the establishment in 2004 of the Packaging Greenhouse, an independent test laboratory for paper and engineering products and services, which played an important part in many regional development projects, as well as the Energy Square (launched in 2007), which aimed to develop new products and services that reduce energy consumption within the global pulp and paper industry.

However, broader attempts towards local industrial diversification were not successful during this period because the representatives of the leading paper and pulp firms in the region could not agree on a common strategy. One of the main obstacles to change at this stage was the fact that the main business of the traditional pulp and paper mills located in the region was packaging (an area of the paper and pulp industry that was not in decline) and they did not see the need for change. Other companies in the region such as machine suppliers and technology consultancy firms (many of them affiliates of large international engineering consultancy firms) were much more open to novel growth paths which opened up new business opportunities; however, their dependence on the large paper and pulp MNCs limited their capacity for change. What existed in the region at this stage was therefore a strongly embedded socio-technical system with no clear motivation for change from a business point of view. In this period, the lack of strategic coupling (or alignment) between MNCs and regional policy makers who perceived the need to create new local growth paths was a significant obstacle to structural change.

The arguments in favour of industrial diversification began to gain increasing support in the paper and pulp industry, both inside and outside the region, from 2012 to 2013 as it became increasingly clear that the traditional business models adopted by the major firms in the industry might not be commercially sustainable over the longer term. This change in the perception of business conditions was the result of both a fall in the global consumption of paper as well as an increasing awareness of the industry's negative environmental impact at a time when sustainable environmental development was becoming a policy priority both within Sweden and at the EU level (e.g. the Lund Declaration of 2009 and the European Climate Change Programme 2000–2004). Interviews with firms and policy makers in the region indicate that this change in business conditions was critical for the creation of a more receptive environment amongst all regional stakeholders for arguments in favour of structural and transformative change. Therefore, what we see is the beginning of a questioning by global industry leaders as well as regional bodies of the sustainability of the dominant socio-technical system in the paper and pulp industry.

Yet, within the region, the challenges associated with the development of a common strategy for industrial renewal and socio-technical transitions were significant. One of the main difficulties confronting PP and its Management Board was that given the importance of MNC affiliates in the local economy (both through their direct investment as well as their influence over suppliers through their control of regional value chains), it was critical to include these firms in any strategy of regional transformation. However, strategic decisions that define the activities of MNC affiliates are usually taken at headquarter level and are driven by considerations which are far removed from the needs of regional development. Therefore, though local management might support regional strategic initiatives which are positive for the locality as well and their affiliates, these proposals for change might not necessarily be supported by headquarters which have different priorities and perceptions of the needs of the whole MNC. Moreover, though local suppliers and service providers might welcome the idea of change, such support may weaken if local collaborative buyer–supplier relationships are disrupted.

What we saw in the Värmland Region at that time is that although important elements of the infrastructure, capabilities and networks that would have enabled the transition towards an environmentally sustainable socio-technical system did exist in the area, the lack of a common regional strategy that could have unified and mobilised local firms or given directionality to the investment of local firms was not present. In the case of this particular region, the deadlock was broken when the leadership of PP in collaboration with the Värmland regional government were able to formulate and articulate a strategy of regional transition towards sustainable development that won the support of global senior managers of MNCs and their regional affiliates as well as other regional firms and stakeholders. Critical to this process was the notion of a *forest-based bio-economy*, a strategy for growth and structural diversification that the mills located in the area could support and sell to headquarters.

6.4.2 A vision and strategy for transition towards a sustainable bio-economy

Critical to Värmland region's success in mobilising regional actors around a common strategy of regional as well as socio-technical transformation was the ability of the leadership of PP to formulate and articulate a regional strategy for growth based on the notion of a *forest-based bio-economy* involving the creation of new regional value chains based on the forestry sector and the use of lignin, a waste material already created by existing paper and pulp mills. As a member of the Management Board of PP noted:

> [T]hree and a half years ago [i.e. 2013], nobody here talked of a bio-economy. Nobody talked about cooperating and different value-chains from the forest, no one … so I think, when I look back, it was about selling a good story about the future. (Interview with a member of the Management Board of PP)

A critical element that galvanised the region into the formulation of a new strategy of regional transition that incorporated the need for sustainability and that later resulted in the notion of a *forest-based bio-economy* was the decision by PP to participate in Vinnova's (Sweden's national agency for innovation systems) Vinnväxt competition. Vinnväxt (Regional Growth through Dynamic Innovation Systems) is a national territorial-based programme which aims to promote sustainable regional growth by developing innovative local environments in specific fields. As part of its mission, Vinnväxt programmes aim to incentivise transformational change towards innovation-driven sustainable growth through the long-term funding of regional initiatives (usually a region receives funding for ten years). The competition for Vinnväxt funding requires regions to formulate a long-term strategy for regional renewal based on innovation and new collaborations (Vinnova 2016) and it explicitly asks regions to work towards ensuring that a proportion of the local economy is based on renewable technologies and practices (interview with Management Board Member of the Paper Province Vinnväxt Initiative):

> The clue was that they asked 'Where will you be in 15 years' time?' and they said 'There has to be a good proportion of renewable'. That was really the important thing. This led us to ask what is renewable? (Interview with a member of the Management Board of PP)

The process of application for Vinnova's Vinnväxt competition opened up an intensive period of collective search and learning amongst firms and regional institutional stakeholders represented on the Management Board of PP to identify a long-term regional sustainable growth strategy. Interestingly, as they prepared their application for the Vinnväxt competition, the Board of PP, including the representatives of the mills and their suppliers, were not clear what could be renewable in the local economy, and numerous workshops, discussions and regional SWOT (strengths, weaknesses, opportunities and threats) analysis were organised around this issue. In the early stages, firms could identify their strengths and the threats they faced, but little clarity existed with respect to future possibilities. Terms such as 'sustainability' and 'bio-economy' were used, but little clarity existed about what they meant.

In their process of search to clarify their strategy, PP came across the notion of a 'forest-based bio-economy', a concept which opened up a scenario of regional renewal that did not challenge the core business or power of existing paper and pulp MNCs. In a forest-based bio-economy, the production of paper and pulp would remain an important part of the regional economy, but the waste produced by traditional paper and pulp manufacturers – above all lignin and heat – would become the raw material for the emergence of new regional value chains. In this scenario, the existing paper and pulp mills could become important players in the creation of new local value chains because of their deep knowledge and capabilities of the process technologies that underpin the innovation in forest-based production. The new strategic idea was therefore to become a large-scale 'regional demonstrator of a forest-based bio-economy' where forest-based industries value chains can be verified, tested and supported. Interviews with local firms and representatives from PP also highlighted that the idea that local firms could contribute to the solution to climate change was an important element of the regional debate, which resulted in the notion of a regional transition towards a forest-based bio-economy gaining widespread support (interviews with representatives of firms and institutions members of the Management Board of PP).

6.4.3 New technological initiatives in the area

In 2013, PP was announced as the winner of Vinnväxt, opening a period of record investment (SEK 130 million over ten years)[1] in the forest industry of Värmland. Winning the competition has incentivised new investments in innovation and industrial renewal, as well as new types of collaborations and networks. At the time of interview, there were 10–15 major innovation projects supported by PP to develop technological and business processes associated with the forest-based bio-economy (this does not include the new investments by the paper mills and machinery and equipment suppliers, which are held under conditions of tight secrecy).

Examples of projects supported by PP include the following.

The LignoCity test-bed

Test-beds are physical or virtual environments in which companies, academia and other organisations can collaborate in the development, testing and introduction of new products, services, processes or organisational solutions. In the case of the LignoCity test-bed, the aim is to develop sustainable processes and products based on the use of lignin as a raw material (at the moment, the lignin value chains are still undeveloped), an area where the region has a strong competitive advantage as lignin is a by-product of pulp mills. The LignoCity test-bed is based on a unique Swedish technology that separates lignin from pulp mills, but can also be used to develop alternative technologies. The project involved opening RISE's demonstration plant to companies interested in evaluating and validating new refining concepts using lignin so that they can develop and scale up the technology to new climate-friendly fuels, chemicals and materials. The project is run by RISE and aims to shorten the time from idea to commercialisation. It is also expected to contribute to the establishment of new companies in Värmland. At the time that this study took place, approximately 20 companies were involved in the project. The project is also part of the region's Smart Specialisation Strategy (http://www.innventia.com/en/About-us/News1/LignoCity–a-new-centre-for-new-green-technologies).

Becoming a regional large-scale demonstrator

Interviews also show that there is a strong belief in PP that the creation of new value chains based on a forest-based bio-economy is not enough and that the success of this regional transformation requires that the region, including the regional government and municipalities, become large-scale 'demonstrators' and users of the bio-economy. The role of public actors in creating demand for bio-economy products, thereby contributing to the creation of a regional market, is seen as a critical element of the regional transition towards a bio-economy. A number of examples were given where public actors could become important users, for example, local hospitals using sheets made from cellulose and a regional and municipal transport system powered by biofuels. This follows already existing examples of municipally owned energy companies that use the waste product from local paper mills (e.g. hot water) as a source of energy.

Regional cooperation for industrial symbiosis within PP

In 2017, PP started a project on industrial symbiosis together with Linköping University, RISE and ten other regional partners. Industrial symbiosis means that residue from one industry becomes the raw material of another. Examples include waste energy from paper mills that can be used by other industries or municipal facilities, but also shared services and logistics solutions. In the project, PP and its partners have to map the different industrial residual streams in the region in order to find circular solutions with multiple beneficiaries.

6.5 The role of agency and the multi-scalar nature of the process of regional transitions to new socio-technical system

As discussed above, a critical factor in Värmland Region's ability to start a process of transition towards a regional forest-based bio-economy was the role of PP. Our interviews indicate that PP was able to develop and articulate a vision of the *forest-based bio-economy* capable of aligning the interests of different regional stakeholders, including the local affiliates of the large MNCs. Moreover, it consistently argued for this idea in the context of significant doubts and initial opposition from a number of powerful MNC affiliates operating in the region. Interviews with local R&D managers indicate that at the time that regional discussions were taking place, the concept of a regional strategy of development based on a bio-economy was very novel. As the R&D manager of one of the large paper mills interviewed explained:

> We were very early to actually put the bio-economy on the agenda – in the Board [Management Board of PP] and in the meetings, to really have that as a strategy. I think we were four or five years earlier than everybody

> else. We were very early adopters of this as a strategy, this is the thing … This would not have happened without Paper Province. (R&D manager, paper mill)

PP also played an important enabling role in the creation of new regional, national and international business and innovation networks that are developing the new forest-based technologies. Moreover, PP and its Management Board has also been a crucial forum for collective learning at the regional level. In collaboration with the Värmland regional government as part of the EU Smart Specialisation Strategy, PP has undertaken a detailed analysis of existing locally based industrial activities and capabilities, knowledge and technology institutions, and infrastructure and the changes required to bring about the transition towards a bio-economy. However, the formulation of the strategy of transitions towards a bio-economy was very strongly influenced by the notion that new strategies for regional development also needed to address societal challenges, in this case climate change (interviews with PP and the Värmland regional government). In this process PP also evolved from being predominantly an industry association representing the interests of firms in the region and creating opportunities for networking to an organisation able to give strategic leadership for a transition of socio-technical system in the region. Our interviews suggest that in this example of regional diversification which involved a process of transition to a new socio-technical system, normal business interactions and market mechanisms would not have resulted in a unified strategic vision. The role of policy-making institutions with a deep understanding of the strategic needs as well as the assets and competencies of the regions was central to the development and implementation of the strategy of regional transitions.

The multi-scalar nature of the transition has also been critical in this process of transition. Though very much focused on the development needs of the region and based on a deep understanding of local assets (the forest), knowledge and capabilities, as well as networks, the process of regional transition has been incentivised, informed and financed by a number of national and international factors. These influences were perceived at different levels, including: the initial incentive to develop a strategy for regional development; the formulation of a regional strategy that also needed to address societal goals; and the need to establish a strategic coupling between the needs of the region and those of the MNC affiliates operating in the area.

6.5.1 The role of regional government and EU policy on clusters and smart specialisation

The Värmland regional government is a member of the Management Board of PP and played a central role in the formulation and development of PP's strategy for regional transition towards a forest-based bio-economy. The contribution of the Värmland regional government has been influenced by its close collaboration with the EU on the formulation of regional strategies for cluster development and smart specialisation. In early to mid-2000s, the regional government set out to challenge the clusters in the region to take on a more strategic role by asking them what kind of local renewal they foresaw for their cluster. In the case of PP, this led to the formulation of the Vinnväxt proposal, which formulated the notion of the forest-based bio-economy.

6.5.2 Vinnova and Swedish national innovation strategy that addresses societal challenges

As discussed above, a critical point in the development of the region was the application for long-term funding from Vinnova's Vinnväxt programme. Vinnväxt's mission is to promote sustainable regional growth and to catalyse a broader transformational change in society towards innovation-driven sustainable growth. The competition demands the formulation of a strategy for regional renewal based on innovation and new collaborations as part of the proposal (Vinnova 2014) as well as a long-term strategic change that addresses issues related to the societal challenges such as climate change and environmental sustainability (interviews with representatives of the Paper Province Vinnväxt Initiative). In its formulation of the forest-based bio-economy, PP was largely influenced by the EU's strategy for a bio-economy and smart specialisation. The notion of addressing climate change has now been integrated into the region's Smart Specialisation Strategy for the region (interviews with representatives of the Paper Province Vinnvaxt Initiative).

6.5.3 The necessity for strategic coupling between the needs of the regions and the MNC affiliates operating in the region

As discussed above, the region hosts a number of MNC affiliates which are deeply embedded in the local economy and are critical to the competences of the region. These firms are also tightly integrated into the knowledge and innovation networks of their parent companies. This double-embeddedness enables these firms to play a significant role in the upgrading of the innovative and manufacturing capabilities of the locality as they can become conduits for the entry of state-of-the-art knowledge into the region. Local affiliates of MNCs can play a significant role in regional renewal when the strategic shifts in the region match the strategic needs of the MNC as a whole. The key point is that the strategic decisions of MNCs are not taken locally, nor are they driven by the needs for regional development; rather, they are driven by the need to meet the interests of global shareholders. When there is strategic convergence between regional development and the needs of MNCs, these firms can bring the significant resources in terms of finance, knowledge and capabilities needed to bring about regional strategic shifts. However, when no strategic match is possible, local MNC affiliates can paralyse regional renewal (as seen in

PP before 2012) or even undermine it by destroying local competences if they withdraw from the area.

The case of PP shows that aligning the interests and strategies of the various MNCs operating in the area and achieving a strategic match between them and the needs for regional renewal can be extremely complex and is often contingent on major drivers for societal change outside the control of the region (in this case major changes in societal values with respect to environmental sustainability and/or radical changes in technology which threaten the existing business models of MNCs).

6.6 Conclusion

This chapter has discussed the initial experiences of regional transition from the traditional manufacture of paper and pulp towards a sustainable forest-based bio-economy. This transformational change represents both a change in the socio-spatial composition of a regional economy as well as a change of socio-technical systems. These major transformations, though still in their initial stages, have been made possible because of the region's deep knowledge of forest-based process technologies and the ability of PP as a cluster organisation to formulate a vision and strategy of regional transformation that unified the main local stakeholders. Directly addressing climate change as a major societal challenge is a central element of the regional diversification strategy, galvanising regional, national and EU support for the new growth path.

The study highlights the role of regional policy-making bodies with a deep understanding of the strategic needs as well as the assets and competencies of their regions as critical agents of regional renewal. This is associated with their ability to formulate new strategies of regional transformative change and mobilise regional stakeholders in processes of learning, searching and implementation. In our study, the ability of regional bodies to play this role was strongly influenced by their interactions with national and EU bodies, which informed, supported and funded their efforts to promote regional transitions.

In the case of a region where MNC affiliates play such a strong role in the local economy, transformational change of socio-technical system required the strategic coupling between the new regional growth paths and the long-term objectives of the global MNCs in the area. In this particular case, a strategic coupling was possible because the sustainability of the existing socio-technical system was beginning to be questioned not only at a regional level but also at a global level, and because the new strategies for regional transformation did not challenge the core business or power of existing MNCs. On the contrary, the notion of the forest-based bio-economy can open up a wide range of new business opportunities for existing firms. However, the experience of the region also shows that when no strategic coupling is achieved, MNCs can block efforts towards both regional diversification when these involve changes in socio-technical systems.

Note

1 The total project budget for PP is SEK 130 million over ten years. Half of the funding comes from Vinnova and half from regional co-funders, such as Värmland Region, Karlstad University, the Värmland municipalities, the County Administrative Board, the County Council, the Forest Board and the PP member companies. See https://www.kau.se/en/research/collaboration-researchers/research-collaboration/vinnvaxt-paper-province-20.

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7 Driving factors in the adoption of Industry 4.0 technologies

An investigation of SMEs

Giancarlo Corò and Mario Volpe

7.1 Introduction

The growing diffusion of a new generation of digital technologies is leading to innovations in communication, production and work to such an extent that several scholars agree that it amounts to new industrial revolution (Bianchi and Labory 2018; Brynjolfsson and McAfee 2014; McQuivey 2013; Schwab 2016). This digital revolution, or Industry 4.0 (I4.0), is expected to increase flexibility, reduce lead times, allow mass customization, enable new services based on big data and create appealing work structures (Heng 2014). Productivity gains might be substantial, opening up opportunities in every industry. At the same time, such changes present a number of challenges, the most significant being increasing job substitution and social inequality (Cowen 2013; Frey and Osbourne 2017).

Given the framework presented in Chapter 1, the aim of this chapter is to provide some empirical evidence of the enabling factors that can assist firms' adoption of specific technologies related to I4.0. Drawing on Frey and Osbourne's (2017) argument on the impact of computerization on jobs, our core objective is to explore the relationship between the adoption of I4.0 technologies and either job creation or destruction. Moreover, we are interested in analysing the synergies between the use of digital technologies and firms' internationalization and financial structure.

There are three main contributions that this chapter makes to the current debate. The first is to provide empirical evidence on the degree of adoption of specific I4.0 technologies by different types of firms, using primary data collected via a survey. Despite the amount of attention that I4.0 has received in the media and in the policy debate, little robust evidence is available on the diffusion of such technologies. The second contribution of is to profile what types of firms are more likely to adopt specific technologies; we find that such firms are more likely to employ high-skill workers, have better links with international markets and have good financial leverage. In other words, there are some enabling factors that facilitate firms' adoption of I4.0 technologies. Moreover, it has emerged that firms tend to adopt combinations of such technologies rather than a single one, which is consistent with the theoretical framework of I4.0 (Platform I4.0 2015). Finally, our evidence shows that firms adopting advanced digital technologies also tend to increase their employment in the short term.

Drawing on Arthur (2009), technology is defined here as an assemblage of practices and components, collections or toolboxes to reach human goals. From this perspective, we consider I4.0 as a cluster of technologies characterized by high levels of connectivity that allow data and information integration in the production and consumption activities. More specifically, we consider I4.0 as including the following seven technologies: robotics, the industrial Internet of Things (IoT), smart products, additive manufacturing (3D printing), big data, augmented reality and the virtualization of IT systems (cloud computing). For the purposes of this work, the expressions 'digital technologies' and 'I4.0 technologies' are interchangeable, since they both refer to the above-listed technologies in line with, among others, the EU definition as spelt out in the I4.0 and digital agendas (EU Parliament 2015a, 2015b) following the German policy that introduced the term *Industrie 4.0* for the first time (Kagermann et al. 2013).

The chapter will proceed as follows. Section 7.2 will discuss the economic literature on the potential of digital innovation and technologies for businesses. Section 7.3 will discuss the uptake of the I4.0 model in Italy. Section 7.4 will present the data collection and outline the methodology employed in the analysis. Sections 7.5 and 7.6 will describe the main findings of the survey and will discuss the relationship between adoption of digital technologies and three different enabling factors: internationalization, financial structure and human capital. Section 7.7 will summarize with a few concluding remarks.

7.2 Digital innovation and technological upgrading

The world of digital technologies is commonly linked to what is now called 'Industry 4.0' (Baur and Wee 2015). This, in turn, is usually associated with the emergence of cyber-physical systems – i.e. highly automated and hyper-connected production processes – that are expected to redraw the organization of production inside the factory (Broy 2013), as well as involving the reorganization of supply chains (Platform I4.0 2015) and a reconceptualization of both products and processes (Schmidt et al. 2015). Therefore, the new industrial paradigm is expected to manifest itself in a multi-faceted way with transformations that are widespread and disruptive.

This idea of I4.0 is linked to similar paradigms that have been often referred to as 'Advanced Manufacturing', 'Integrated Industry', 'Smart Industry' or 'Smart Manufacturing' (Hermann et al. 2015). These latter concepts are similar, but tend to emphasize distinct aspects; therefore, there is no consensus on *one* definition of I4.0 (Hermann et al. 2015; Liao et al. 2017). The difficulty in defining the phenomenon is partly due to the different perceptions that companies and stakeholders hold regarding digitization and I4.0. Sommer (2015) has shown that the importance of change is widely recognized, even though very few companies are ready to invest, or are already investing, in that direction.

In the current debate, I4.0 is often assumed to be linked to the Fourth Industrial Revolution (Schwab 2016), following the previous three that are widely accepted in the literature and are associated, respectively, with steam power, electricity and computerization (Rullani 1989). Other authors, by contrast, consider today's digital innovation still as the tail end of the Third Industrial Revolution that started in the 1970s with the introduction of computers in business processes (Gordon 2016). According to Thames and Schaefer (2016), the main goals of I4.0 are to achieve a higher level of productivity and efficiency, as well as a higher level of automation. These will allow mass customization of products, fast adaptation of production chains, innovative value chain organizations, and new types of services and business models (Shafiq et al. 2015, 2016). The economic potential of this transformation could be huge (Rüßmann et al. 2015), but its evaluation is very difficult because of the vast number of technologies involved and of the different maturity levels for each of the technologies (Schröder 2016; Hermann 2015; Hofmann and Rüsch 2017). For a more detailed literature review and discussion of I4.0, see Liao et al. (2017), Lu (2017) and Kang et al. (2016).

Although the aim of this chapter is not to elaborate on whether I4.0 is associated either with a revolutionary industrial paradigm shift (Schwab 2016) or with an evolutionary process of digitalization that started in the 1970s (Gordon 2016), it is worth highlighting a couple of points that will help frame the following empirical analysis. Firstly, there are some elements of originality in the current phase of digitalization that distinguish 'Industry 4.0' from the computerization of the 1970s and 1980s, such as the combination of different technologies into cyber-physical systems and cloud-based manufacturing (Thames and Schaefer 2016). In particular, we recall some elements of the literature on digitalization and ICT technologies that can also apply to I4.0, but that have not yet been explicitly investigated by the I4.0 literature. The existing literature on ICT has mainly highlighted the difficulties in estimating the value generated by digital technologies (Grover and Kohli 2012; Yoo et al. 2012) and, consequently, in assessing the impact of the ongoing transformation. Due to the ever-increasing technological integration, the 'digital' side is difficult to evaluate separately from the 'non-digital' side.

Secondly, another problem is represented by the lack of shared criteria to identify what makes a business 'digital' or part of the I4.0 paradigm. Thus, the implementation and adoption of digital technologies by firms surely depend on the IT infrastructure. Although these are essential for further development, it may be misleading to consider this digital upgrading only as a part of an evolved ICT system (OECD 2014). Previous studies have also emphasized that digitalization and IT promote access to innovative ideas (Pisano and Verganti 2008), mainly sustaining the knowledge flow (Katz and Rice 2002) and changing how individuals interact (Hinds and Kiesler 2002). Therefore, openness and the creation of networks are essential in order for firms to compete. Firms will improve the relationship between individuals and business practices with internet-based technologies (Vaccaro and Madsen 2009), thus enabling digital technologies to create new types of innovation processes (Henfridsson et al. 2014).

Thirdly, firms need to design and implement an appropriate joint IT and business strategy depending on their competitive context, creating a digital organization and IT capabilities in order ultimately to be able to create value from digital innovation (Fichman 2012). Mere investments in IT infrastructure and related technologies are not enough, even though a well-designed IT architecture is essential to develop new products and processes (Fink 2007). Evidence shows that social and organizational capital both have a positive relationship with the adoption of innovations (Dost et al. 2016).

Fourthly, the ability to collect and manage multiple types of information is crucial for the innovation and exploitation of digital technologies (OECD 2015). Managing big data (Lycett 2013) is the key to creating value, employing information that is usually already available and whose potential only needs recognition in order to be released (Fosso Wamba et al. 2015). No evidence of a widespread awareness of the importance of data is available, as academics have in fact put forward very few models to evaluate the maturity level of data management (Comuzzi and Patel 2016). Thus, the main barriers to create value from data management and analytics are mainly managerial and cultural at the firm level rather than related to the technology itself (La Valle et al. 2011). Overcoming such barriers could lead to an improvement in firms' intellectual and human capital (Secundo et al. 2017), which might benefit both businesses and individuals. Furthermore, the impact of data management is not limited to already existing business models; it can also enable the creation of brand new data-driven business models (Hartmann et al. 2016).

Further, evidence shows that investments that do not involve human capital are less likely to lead to productivity gains, especially in small firms (Díaz-Chao et al. 2015). In fact, a positive relationship between product, service and process innovations and 'innovative human capital' has also been observed (McGuirk et al. 2015). Although there is no consensus that improving human and intellectual capital will enhance innovation in the broader sense (Buenechea-Elberdin 2017), it seems essential to accomplish digital transformation. For instance, Cirillo (2016) shows that hi-tech industries, influenced by international contexts, usually show greater productivity, accompanied by employment growth associated with high-skilled talent. Conversely, low-tech industries require lower-skilled workers, command lower wages and rely on more flexible labour. At present, learning by doing and intra-firm training are both essential. Evidence from Evangelista et al. (2014) indicates that in order to leverage the adoption of digital technologies, life-long learning seems to be more important than formal education.

Finally, openness to international markets has a positive impact on innovation activities in both large and small enterprises (Boermans and Roelfsema 2016). Access to international markets allows firms to benefit from economies of scale to pay back the fixed costs of innovation, and enables entrepreneurs, technicians and managers to be part of wider knowledge networks. A positive link exists not only between internationalization and innovation, but also between these two factors and productivity (Altomonte et al. 2013). Moreover, several empirical studies confirm a positive correlation between the use of digital technologies and export activities (Morgan-Thomas and Jones 2009; Higón and Driffield 2011; Bianchi et al. 2016; Cassetta et al. 2016). However, almost all of them consider the front-end applications of digitalization, using variables such as the use of ICT, social media and e-commerce. Conversely, the digitalization of productive processes has so far been under-studied.

7.3 Industry 4.0 in Italy

I4.0 has become a highly debated topic in Italy only in the last couple of years. For a long time, the discussion concerned a superficial interpretation of the German model, often focusing on a few single technologies. Recently, the attention has been shifting towards a more holistic and realistic vision.

From recent studies (Federmeccanica 2016; Fondazione Nord-Est 2015), it has emerged that the adoption processes of some technologies seem to be already in place. Indeed, views collected from entrepreneurs and managers seem to suggest that some technologies – such as additive printing, 3D scanning and advanced cutting systems – are basically an evolution of technologies already in use, greatly reducing the costs involved in the adoption of their later generations. On the other hand, the adoption of the IoT and virtual reality is, for instance, still limited and distant from many businesses' daily activities. This can be explained by the radical change of technological paradigm under way and thus of the consequent new business models that many of these technological solutions involve (e.g. in relation to the most extreme forms of servitization). In such a delicate transition, Italian firms tend to rely too little on the knowledge and expertise they could access from universities and research centres.

It is clear that the debate on the Fourth Industrial Revolution has so far been strongly linked to technological aspects, mostly driven by the narrow German model that has led the way. This technological primacy has contributed to creating a climate of mistrust and concern amongst businesses, especially amongst small and medium-sized firms which cannot fully understand the potentials that such technologies present to them. These doubts also arose from the way in which I4.0 was presented to companies with a strong emphasis placed on the adoption of, for instance, robotics, sensoring and relatively high-cost technologies, which small businesses have struggled to recognize as relevant for them, given the business model that has characterized their competitive advantage for years. Therefore, it is crucial to shift the debate on I4.0 from the mere technological aspects to a more systemic vision that has been captured in this volume using the term Industry 4.0+.

The Italian government launched a national plan to support the upgrading of firms' machinery stocks in 2016: the 'Piano Industria 4.0'. This provided financial support to firms of any size and industry to buy new machinery and equipment. Superficially, this seems to be endorsing an understanding of I4.0 as purely associated with the technological content of firms' capital stocks; however, the small size of the majority of Italian firms had prevented them in the recent past from undertaking the necessary investments to keep up with advances in technology. Besides, Italy has a very competitive and export-oriented mechanical engineering sector that nevertheless benefited from a boost in domestic demand. Therefore, the government plan must be understood as acting on two levels: firstly, to raise awareness of what I4.0 might mean and imply; and, secondly, to encourage firms to inject some technological upgrading in their production. The initial plan expected a private commitment of over €56 billion for the period 2017–2020, in view of a public commitment of around €24 billion.

7.4 Case study of I4.0 in Veneto

To analyse the diffusion of digital technologies in Veneto, a survey was administered to manufacturing, construction and services companies during the autumn of 2015. The aim of the survey was to investigate the awareness and diffusion among firms of the following technologies: automation and robotics, the industrial IoT, smart products, additive manufacturing, mixed reality, big data and the virtualization of IT systems. The survey also included in-depth questions on additive manufacturing. Firm case studies with structured interviews followed the collection of data.

7.4.1 Data and methodology

Primary data collection was carried out through an online survey administered in the autumn of 2015 to a stratified sample of firms in the Veneto region; the survey was facilitated by the Chamber of Commerce of Treviso and Belluno. The targeted sample of firms for the survey was selected according to the following criteria: manufacturing firms must have had at least six employees and a minimum of €1 million production value; construction firms must have had more than 20 employees; and service firms must have had at least three employees and a minimum production value of €250,000.

Table 7.1 shows the number of respondents, divided by sector. Sectors were identified according to the NACE rev. 2 classification. The sub-division was

Table 7.1 Respondents by sector: absolute numbers and percentages

Sector	*Respondents*	*Percentage of total*
Manufacturing	633	71.04
Construction	56	6.27
Services	202	22.69
Total	891	100

Source: Authors' elaboration.

operated as follows: manufacturing NACE section C; construction NACE section F; and services NACE sections J and M. The total number of respondents was respectively 633, 51 and 207; the sample is representative in terms of company size and industry.[1]

Firms were asked if they were familiar with and if they used any of the following digital technologies: robotics and automation, the industrial IoT, smart products, 3D printing, big data, mixed reality (virtual and augmented reality) and virtualization of IT systems. The questionnaire included an accurate definition of each technology in order to clarify and facilitate the comprehension of the task. In the construction and service sectors, 'digital users' were defined as firms adopting at least *one* of the digital technologies, and in the manufacturing sector, 'digital users' were firms that adopted at least *two* different technologies. This distinction was necessary in order to shed light on the effects of a combination of different technologies; this appears to be very important for the manufacturing sector.

For all surveyed firms, we were also able to collect administrative data on employment, trade and financial structure from secondary sources for the years 2007–2014. Data on human capital were sourced from 'Veneto Lavoro', the Regional Agency that records all the hiring and cessation movements occurring in the labour market. Data on import and export activities were extracted from the Infocamere and ISTAT databases. Finally, financial data were accessed from the AIDA database (the Italian database available from BvD). These three databases were aligned with the survey database, allowing us to build a unique firm-based dataset with information on the composition of the workforce, the import and export activities, and the financial structure. We analysed this rich database with robust descriptive statistics (Sections 7.5 and 7.6 below).

7.5 Main findings

7.5.1 Awareness and adoption of new digital technologies

The diffusion of digital technologies in the Veneto region varies across industries. The shares of digital users (as defined above) in the manufacturing and construction sectors are respectively 37% and 33%, while it is 64% for services. Therefore, awareness of digital technologies seems to be higher in services and lower in construction. We find the existence of different technological frontiers among sectors. Intensity of use and types of technologies are significantly different depending on firms' activity.

There is also an important gap between levels of awareness and adoption of technologies. Both seem to be the highest in relation to additive manufacturing: 60% of firms declare that they know of the technology, but less than 10% use it. The difference in this case – as well as for other technologies – is possibly due to the fact that firms do not use a specific technology in their specific business, but part of the adoption gap can also be explained by a superficial knowledge by firms of the possibilities and impact of such digital technologies on their business.

Analysing additive manufacturing in particular, what emerges is that it is only used in less than 10% of firms and it is weakly integrated in business processes. We find that smaller firms have been able to better integrate 3D printing technology in their business and there is no significant impact of the technology on the labour market. Very few jobs were created and in most cases its introduction did not require particular adjustments in terms of labour organization. Furthermore, 3D printing technology is still linked to prototyping, with more than 90% of firms using it for that purpose. Less than 30% of respondents declared that they use additive manufacturing for the fabrication of finished or usable products.

Given its sectoral specialization, Italy could greatly benefit from the large number of applications related to the adoption of the latest generations of additive manufacturing technology (Bai et al. 2017). However, the level of adoption in Veneto is still too limited: we find that 51% of firms are additive-detached, 37% are additive-integrated and only 12% can be considered as additive-oriented. Table 7.2 shows our findings in terms of firms' awareness and adoption of digital technologies. It is also worth noting the size of the gap between the firms that declare that they are familiar with some digital technologies and those that actually use them. As expected, we find considerable differences in the diffusion of digital technologies among sectors, with the virtualization of IT systems being the most widely adopted technology, whereas others are more sector-specific.

No relationship between the size of firms and the number of technologies adopted was found. This evidence is consistent with the idea of firms having their own technology frontiers, meaning that each firm selects a specific set of technologies and combines them according to their own specific needs and activities. For example, among the manufacturers of plastic products, it can be noted that 89% of them use robotics or automation, while none of them declare that they have introduced sensors in 'smart' products.

7.5.2 Clusters of technologies

We would argue that the multiple use of technologies can be more significant than the adoption of a single technology for firms. Having found that the size of firms does not play any role in relation to technological adoption, we began to explore whether firms' adoption could depend more on firms' specific technological frontiers or families of technologies they related to because of the sector or activities in which they were specialized. Within this logic, individual technologies were grouped together on the basis of complementarity. Figure 7.1 maps what we found from our survey in terms of technological combinations that firms disclosed. In this network of technologies, the size of the nodes denotes how many times a single technology is used together with another, while the thickness of the links represents how much two technologies

Table 7.2 Awareness and adoption of digital technologies (% of total)

Technology	*Manufacturing*		*Construction*		*Services*		*Total*	
	Knowledge	*Use*	*Knowledge*	*Use*	*Knowledge*	*Use*	*Knowledge*	*Use*
Robotics	52.66	26.59	32.08	4.04	29.81	7.68	48.82	24.13
Industrial IoT	37.04	13.84	21.49	9.37	33.06	9.25	38.16	15.71
Smart products	27.35	5.23	23.05	9.37	28.86	7.78	30.98	7.63
3D printing	58.57	8.34	44.06	1.56	52.27	6.68	58.47	13.13
Big data	25.60	9.49	28.18	12.94	36.49	20.96	34.34	17.06
Mixed reality	32.45	6.36	30.66	4.04	37.60	16.96	38.61	11.90
Virtualization of IT systems	39.93	16.87	40.32	30.22	55.56	45.21	53.65	33.67

Source: Authors' elaboration.

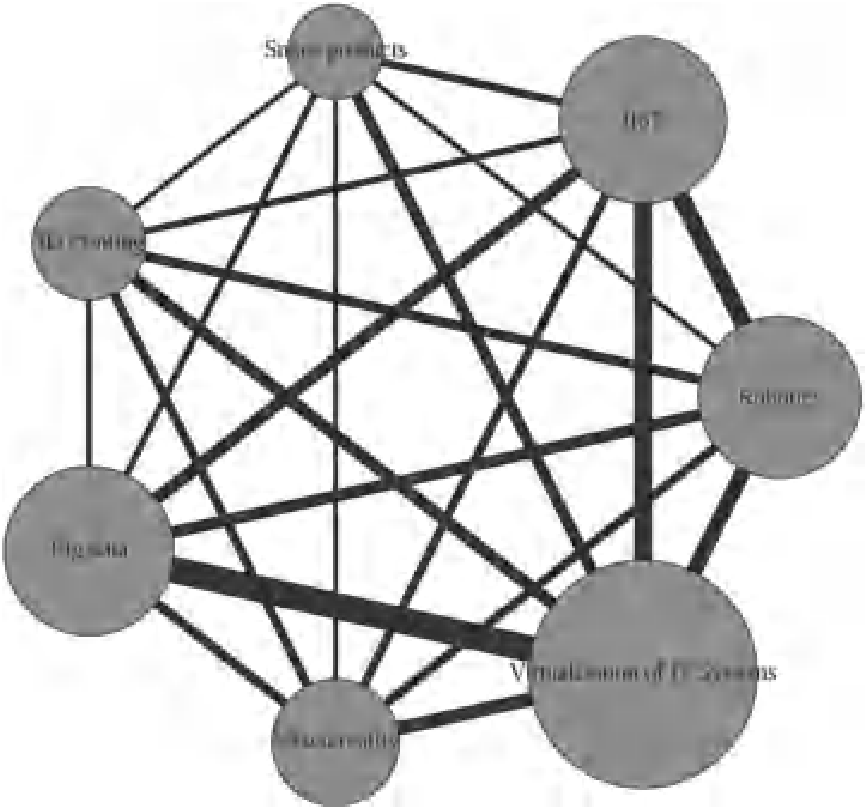

Figure 7.1 Combination of different technologies.

Source: Authors' elaboration.

Notes: The dimension of vertices expresses the number of times a single technology is used together with another. The width of the lines represents the number of times the two technologies are used together.

are used together. Some technologies show a higher level of complementarity than others. Potential clusters of technologies seem to emerge around robotics, the industrial IoT, big data and the virtualization of IT systems. This makes sense since all these technologies are often used together in advanced automation processes. Our evidence is coherent with the theoretical framework of I4.0, where value is created by combining different technologies (Schimtd et al. 2015). Furthermore, the creation of cyber-physical systems, which are the result of the application of I4.0 technologies, necessarily requires the combined adoption of multiple technologies such as robotics, the IoT and big data (Broy 2013; Evangelista et al. 2014).

7.6 Enabling factors

We move on to investigate three other enabling factors impacting on the adoption of digital technologies by firms. These are the quality of human capital in firms, their openness to international markets and their financial structure. We consider each of them in turn.

7.6.1 Human capital

Digital users and non-digital users vary in terms of the composition of their workforce. The most significant finding is that digital users employ more highly skilled workers, i.e. people with a degree or high school education (see Table 7.3). This applies to all sectors, even though the difference is more evident in the construction and service sectors. Furthermore, firms using technologies created more jobs in the period 2012–2014 (see Table 7.4). Specifically, the highest growth occurred for highly skilled workers and for those with a degree. Another important fact is that whether or not they use digital technologies, most of the surveyed firms no longer hire unskilled workers. This will result in firms having an increasingly large share of highly and medium-skilled people in their labour and contracting out low-skilled functions.

In the period 2012–2014, digital users (accounting for roughly one-third of the total number of firms) exhibited net occupational growth, recruiting more than 75% of all the jobs created within the sample firms. This is only partially consistent with evidence from other major European countries, where job creation is led by product innovation and an increase in value added (Cirillo 2016). Investments in technology can be interpreted as process innovation and should

Table 7.3 Composition of the workforce in 2014 (% of total employment)

	Manufacturing		*Construction*		*Services*		*Total*	
	Digital users	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*
No skills	12.31	10.91	10.64	16.65	0.49	3.88	10.90	10.80
Low skills	46.18	50.81	36.17	55.81	2.55	10.60	40.75	48.25
Medium skills	16.65	16.93	21.28	13.53	34.71	54.96	18.93	19.44
High skills	24.85	21.35	31.91	14.01	62.26	30.56	29.42	21.51
No academic qualifications	1.87	2.79	2.98	5.24	0.45	1.61	1.77	2.87
Compulsory schooling	38.41	46.54	36.14	59.81	4.57	14.13	34.33	45.03
High school	45.02	42.61	45.47	30.78	56.92	49.69	46.43	42.33
Degree	14.70	8.05	15.41	4.17	38.06	34.57	17.47	9.77

Source: Authors' elaboration.

Table 7.4 Employment growth 2012–2014 (% of total employment growth)

	Manufacturing		*Construction*		*Services*		*Total*	
	Digital users	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*
No skills	–1.24	–5.16	–9.52	21.93	-20.00	9.68	–1.88	–2.52
Low skills	6.67	1.43	0.31	6.15	13.51	10.71	6.35	1.93
Medium skills	6.76	3.75	–2.56	1.80	2.88	4.10	5.27	3.73
High skills	12.48	5.73	11.76	1.74	2.81	-2.19	10.01	4.68
Without academic qualifications	-5.53	5.31	-14.81	160.00	40.00	-7.14	-5.62	13.14
Compulsory schooling	–0.40	–4.15	–0.71	4.95	–5.33	–6.56	–0.50	–3.44
High school	12.18	8.14	1.15	0.88	3.76	5.53	10.22	7.51
Degree	23.28	12.58	19.00	29.17	1.72	4.49	16.78	10.73

Source: Authors' elaboration.

thereby have a negative impact on employment; however, our findings suggest that process innovation can be associated with employment growth, driven by productivity growth and new skills requirements. The data in Table 7.4 have to be interpreted in the light of the severe economic crisis that plagued the Veneto production base. Our findings suggest that access to high-skill labour was able to compensate for the negative business environment of the manufacturing and construction sectors in the mid-2010s; however, this was not the case for services, probably because the latter focused too narrowly on the local market (see Table 7.5).

7.6.2 Firms' internationalization

Firms' openness to international markets is one of the factors that enable and accelerate the adoption and diffusion of digital technologies. Our findings on the relationship between firms' import/export activities and firms' adoption of digital technologies are reported in Tables 7.5 and 7.6.

In the present analysis, we find that digital users are more open to international markets. The openness to international markets plays a significant role, but only if digital users are strictly defined (i.e. at least three technologies are used). Such a relationship can be seen from two different perspectives. Firstly, digital technologies can represent both a requirement for and a consequence of internationalization. Competing in international markets is likely to be more challenging than doing so in local markets, forcing firms to invest in digital technologies in order for them to reach productivity levels comparable to those of their international competitors. Thus, digital users have effectively higher

Table 7.5 Share of respondents that have export activities, divided by digital use (% of total)

	Digital users		*Digital non-users*	
	Export	*Do not export*	*Export*	*Do not export*
Construction	30.35	69.65	8.66	91.34
Manufacturing	73.69	26.31	58.27	41.73
Services	8.98	91.02	3.70	96.3

Source: Authors' elaboration.

Table 7.6 Share of respondents that have import activities, divided by digital use (% of total)

	Digital users		*Digital non-users*	
	Import	*Do not import*	*Import*	*Do not import*
Construction	48.51	51.49	10.59	89.41
Manufacturing	57.95	42.05	47.39	52.61
Services	5.83	94.17	8.30	91.70

Source: Authors' elaboration.

productivity performances than digital non-users. Secondly, engaging in import and export suggests that such internationally exposed firms operate in global value chains; for them, digital adoption might be necessary in order to collaborate with foreign partners in the supply chains.

7.6.3 Financial structure and economic performance

We finally looked at the financial position of firms in order to shed light on the relationship between the adoption of digital technologies and firms' economic performance, as well as looking at firms' access to capital. Specifically, the present investigation focused on the profitability (return on sales (ROS), return on equity (ROE) and return on investment (ROI)), productivity (value added per employee) and capital composition (Leverage, Net Financial Position and Debt/Equity) of firms (see Table 7.7 for details).

Digital users generally show a better financial composition (see Table 7.7). No great differences are evident on the leverage ratios, all being well below the limit of 3%. Additionally, the net financial position (NFP) is considerably higher for firms adopting digital technologies than for firms not adopting digital technologies.

Finally, considering profitability ratios, higher returns can be observed for firms that employ digital technologies in the construction and service sectors. Conversely, for manufacturing firms, the findings are less clear. In particular,

Table 7.7 Average financial ratios, separating the firms that adopt digital technologies from those that do not

	Manufacturing		*Construction*		*Services*	
	Digital users	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*
ROS	6.17	4.78	5.67	1.90	5.75	1.79
ROE	13.65	14.73	19.61	8.12	23.71	6.92
ROI	15.47	15.70	6.36	1.35	32.04	3.86
Value added per employee	65.27	56.45	73.89	49.98	60.62	65.08
Leverage (L)	1.28	1.52	2.34	1.29	1.17	2.07
Net financial position (NFP)	4.413	669	11.467	1.919	121	973
Debt/equity	1.03	0.82	0.70	1.80	0.47	1.37

Source: Authors' elaboration.

Note: The value added per employee and the net financial position are reported in thousands of €. ROS, ROE, ROI and Leverage are percentages.

digital users show a higher return on sales ratio, while ROE and ROI are higher for digital non-users. Nevertheless, the differences are not particularly significant. Additionally, the value added per employee ratio is higher for digital users in the manufacturing and construction sectors; however, in the service sector, digital users show a lower productivity ratio, suggesting that for them, the adoption of digital technologies does not translate into significant improvements in productivity.

However, we found the low profitability ratios for digital users in the manufacturing sector puzzling and we tried to understand the reasons for this. Our analysis finds that firms are adopting the first wave of I4.0 technologies, but have problems that are often related to learning processes. Moreover, innovative firms seems to have higher capital intensity and greater equity and risk capital in their financial position. This kind of capital allows firms to overcome asymmetric information constraining access to credit access and allows them to have more time to benefit from the initial investment.

Secondly, we find that human capital is most important in firms' value added; we looked at the ratio labour cost (wL) over value added (VA) and compared it with high capital intensity. We find that as firms employ more highly skilled employees, their wage bill increases and so does the wL/VA ratio. In other words, firms' lower business profitability in the short term is explained by investment in greater skills and to a lesser extent in fixed capital. Table 7.8 below shows human capital does not account for a greater share of value-added digital users across all sectors. Therefore, the explanation for the low profitability of manufacturing digital users might lie in the reinvestment of the created value and the longer-run ROI. The adoption of digital technologies requires a series of risk investments, such that the higher value created

Table 7.8 Distribution of the value added between human and risk capital

	Manufacturing		*Construction*		*Services*	
	Digital users	*Digital non-users*	*Digital users*	*Digital non-users*	*Digital users*	*Digital non-users*
wL/VA	0.63	0.76	0.71	0.86	0.71	0.84
EBITDA/VA	0.37	0.24	0.28	0.11	0.27	-0.02
EBIT/VA	0.26	0.12	0.19	0.03	0.17	-0.40

Source: Authors' elaboration

Note: Each indicator is calculated as an average over the last nine years, then considered in logarithmic value.

has to be reinvested in a company's activities instead of being distributed to shareholders. This would keep the ROI and ROE low. Although no data on the levels of investments are available, early indications point in this direction. For instance, the amount of the net fixed assets is four times higher for digital users than for digital non-users (€16 million against €4 million of digital non-users). This hypothesis needs further testing that is beyond the scope of this chapter (Aboal and Garda 2015).

The same conclusion can be drawn considering the Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA)/VA ratio (or EBIT/VA, thus mitigating the weight of capital-intense activities). In this case, though, a lower ratio would translate into a higher value added attributed to human capital.

7.7 Key findings from the empirical evidence

This chapter introduced the debate about I4.0 in Italy with the launch of the 'Piano Industria 4.0' by the government in 2016. We focused our attention on the diffusion of digital technologies in the Veneto region, as one of the country's most manufacturing-intensive regions. The main findings of the case studies are summarized below.

The first key finding is that firm size does not matter in terms of explaining the rate of adoption of I4.0, especially digital technologies. This confirms a similar result regarding Portuguese firms, also indicating a low correlation between size and the adoption of digital technologies (Faria et al. 2002).

The second key finding is that the adoption of digital technologies seems to cut across sectors. The present analysis shows the existence of different technological frontiers from one sector to another. However, we find that manufacturing firms are less likely to adopt technologies than those in the construction sector, and firms in the service sector show a more significant process of adoption. This finding can be explained by the nature of the manufacturing sector in Veneto, where small and medium-sized enterprises (SMEs) operate mainly in industries that have a competitive advantage in terms of design and innovation rather than in terms of price, the so-called 'made-in-Italy' industries such as eyewear, fashion, jewellery and furniture.

Thirdly, we find that firms' international exposure matters: firms' adoption of digital technologies is linked to their engagement in international markets, which is measured by the presence of import and/or export activities. This applies to the manufacturing and construction sectors, but not to services. We find a significant and positive relationship between firms' international exposure and the adoption of digital technologies. This relationship can be explained on two levels, since internationalization is simultaneously a consequence of and a requirement for the adoption of technologies. On the one hand, intense competition in international final markets requires flexibility and productivity levels which can only be achieved through digitalization; on the other hand, the growing need for firms to ingrate into the global supply chain can only be satisfied through ICT-related technologies, forcing them to keep up their technological readiness with global buyers.

Fourthly, another crucial finding is certainly that regarding human capital. The analysis shows that the quality of human capital is significant and positively related to the adoption of technology. We used two proxies for measuring the quality of human capital (the percentage of graduates among all employees and the percentage of highly skilled workers) and they both reinforce the argument that human capital is essential for the adoption of technologies. Analysis of the composition of skills suggests that digital users are characterized by more highly skilled and highly educated workers than digital non-users. Evidence from this study also shows that the digital users are mainly hiring skilled and educated workers. In the period 2012–2014, digital users from the present sample recorded net occupational growth: one-third of the firms accounted for 75% of all new jobs.

Finally, three different indicators were used to analyse the financial position of firms: the net financial position, the EBITDA and the debt/equity ratio. Of the three alternatives, the more significant indicator appears to be the EBITDA. Therefore, the ability of the firm to create significant and steady earnings seems to positively relate to the adoption of digital technologies. Lower ROI and ROE for digital users suggests that investments in new technologies will deliver over the longer term. Overall, digital users record a better productivity index than digital non-users. The empirical evidence suggests that internal resources represent a strong driver towards the adoption of technological innovation, as is the case in Guarascio and Pianta (2016).

7.8 Some policy considerations

Factors enabling an efficient use of digital technologies have to be identified to redirect companies and public investments. The present study and several others underline the value of intangible assets. Specifically, a specialized workforce, quality relations with suppliers, company know-how, wise management and accurate organization all allow the profitable exploitation of digital technologies. Hence, the adoption of a single technology might in itself be necessary, but far from sufficient. Therefore, our empirical analysis suggests the crucial role of human capital, which emerges as a key factor in the adoption of digital technologies. Consequently, public policies stimulating investments in the adoption of specific technologies (often embodied in machinery or equipment), like the Italian government's 'Piano Industria 4.0', should couple the technological aspect with the human capital aspect. In our view, the incentives in technology adoption should request a mandatory presence of adequate workers in the firm. Alternatively, the investments in new machinery should be combined with the hiring of new workers and/or with specific learning processes.

To capture all the potential value that digital transformation can add, it is necessary for a company to broaden its horizons and look beyond technological considerations. Hence, a supporting ecosystem that can promote and facilitate the adoption of technologies is essential to enable companies to keep up with their competitors. In doing so, any ideological position on technical revolutions and new industrial paradigms should be disregarded. Each company should choose its own model on the basis of its traditions and needs. Therefore, imposing the same business model on all companies is certainly not feasible and would surely deplete the efforts made and the potential benefits deriving from the implementation of the model. We have seen that digital technologies are not linked to a particular economic sector, but are used across all of them, although with different diffusion rates. This means that policies targeting firms as end-users of digital technologies should not be sector-specific, but should promote a diversity of firms and products, thus boosting territorial resources.

The complex 'job versus technology' issue should also be examined. Clearly, the labour market needs to adapt and adjust. However, concerns about robots replacing human workers are often likely to be speculative and not based on reality. Although the data presented in this work are limited and call for further analysis, our findings suggest that human capital is one of the most crucial elements for the digital transformation. Specifically, fieldwork conducted for this project clearly shows that a technological upgrade is generally accompanied by employment growth, especially in SMEs. This is very important in fragmented systems where no big players dominate the market, as is the case in Italy and most of Europe. Therefore, understanding the true situation is crucial for the realization of benefits and in order to avoid negative effects, whether we are observing a revolution or not.

7.9 Disclosure statement

No potential conflict of interest was reported by the authors.

Note

1 The composition of the sample was statistically tested. The chi-squared test (Pearson 1900; Plackett 1983) confirms that the composition of the universe and the sample correspond, both in terms of dimension and in terms of activities.

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8 Exploring Industry 4.0 production in Sweden

Claudio Fassio and Max Nathan

8.1 Introduction

Like many industries before it, manufacturing is being 'disrupted' by new technology. This 'Fourth Industrial Revolution' (Schwab, 2017) or 'Industry 4.0' (Brettel et al., 2014) promises substantive productivity and growth effects via the application of technologies such as sensors, nanotech, RFID chips, robotics, machine learning and AI to a vast range of industrial settings (Brynjolfsson and McAfee, 2014). The general purpose nature of many of these technologies (Bresnahan, 2010) is said to promote recombinant growth (Kremer, 1993) both through the reconfiguration of existing production lines, products and services, and the development of entirely new ones.

Much of the existing analysis on the Fourth Industrial Revolution and the implications for the so-called new manufacturing model called Industry 4.0 has focused on *users* and, more broadly, on industry awareness and levels of readiness in existing businesses (Brettel et al., 2014; Lee et al., 2014, 2015; Schwab, 2017). In contrast, we look at the evolution of Industry 4.0 *producers*, specifically science and technology companies in Sweden during the 2000s and early 2010s. We use rich microdata from the Swedish MONA dataset to do this, and provide results both at the national level and at the municipality level, identifying clusters in Stockholm and other Swedish cities.

Sweden is a particularly interesting country to study in relation to what Swedish policy makers call *smart manufacturing*. Its industrial heritage – in particular, its historic strengths in electrical engineering and mobile communications – means that hardware firms can potentially draw on a rich 'ecosystem' of high-value manufacturing knowledge, suppliers and collaborators, and a thick labour market of skilled and experienced workers (Brown and Mason, 2014; Spigel, 2017). Unlike Germany, which combines large conglomerates with the 'Mittelstand' of small and medium-size firms, Sweden's industrial economy remains dominated by large MNEs, plus a cadre of specialist ICT consulting companies (Gens et al., 2015; Giertz, 2015a). Furthermore, in the early 2000s, Ericsson shed around 50% of its workforce: many laid-off workers have either started their own businesses or have moved into consultancy roles, diffusing technical know-how further through the economy (Chaminade et al., 2010). Relatedly, Stockholm has become one of Europe's leading technology hubs, with both thousands of young tech companies and some global players such as Skype, Spotify, Mojang and Klarna (Semuels, 2017).

Furthermore, Sweden has a tradition of hands-on industrial policy: national and local policy makers are actively trying to encourage the adoption of new technology across a range of sectors and firm types and a shift towards smart manufacturing. Much of this has been in response to the so-called 'Swedish Paradox' – high levels of R&D spending but low productivity (Bitard et al., 2008; Ejermo and Kander, 2009), which, it was argued, may be partly explained in Schumpetarian terms by a lack of new entrants who bring new ideas to the market (Aghion et al., 2009).

The chapter is organised as follows. Section 8.2 sets out some key concepts and the country context. Section 8.3 describes our methodology. Section 8.4 discusses results. Section 8.5 gives brief conclusions.

8.2 Framework

8.2.1 Defining Industry 4.0

'Industry 4.0', the 'Industrial Internet' and the 'Fourth Industrial Revolution' (FIR) are fuzzy terms with no standardised definitions (Giertz, 2015a; Gens et al., 2015). Its components can usefully be seen as a 'technology-product-industry space'; that is, an evolving set of technologies, product/service applications and industry specifics.

Commonly cited FIR *technologies* include sensors and radio chips, AI, machine learning; 3D printing, nanotech and cloud computers. Many of these have general purpose characteristics (Bresnahan, 2010; Perez, 2010) and can be applied to a vast range of *products and services* (Brynjolfsson and McAfee, 2014). These include some wholly new or 'recombinant' use cases (Kremer, 1993), such as new 'smart objects' of varying complexity (such as wearables or drones), as well as existing activities (such as automated production lines), computerised/digitised products (such as medical devices) and components (such as airbags). These new products typically require associated *software*, in apps and or other control systems. In any given industry, a range of *services* also builds on these, especially data and analytics around a product (servitisation), consultancy and training.

Almost all manufacturers could be *users* of these new technologies. We focus on the (smaller) set of *producers* – firms whose sole or principal output are products in the FIR technology space, or services derived from such products. In practice, these firms cover a number of industries typically considered as science and technology, but also advanced manufacturing, medicine/pharma, consumer electronics and specialised software/support.

8.2.2 From technologies to ecosystems

More broadly, and following Freeman (1991) and Perez (2010), we can place these components in a larger, dynamic 'technology system', that is, a set of multiple technologies and its linked network of producers, suppliers, distributors and users. Technology systems benefit from (potentially substantial) internal spill-overs. Perez (2010: 187) argues that as 'technologies interconnect and tend to appear in the neighbourhood of other innovations', innovations in one part of the space tend to induce complementary (e.g. downstream) innovations in other parts. These spill-overs are likely to exist in both technology space (e.g. recombinant use cases) and physical space (clusters of firms that interact and learn from each other).

Industry 4.0 producers are knowledge-intensive businesses in which symbolic and physical product and service creation is a central activity. As Mudambi (2008) points out, value creation is mostly created at the upstream and downstream ends of a production function: ICTs, in theory, allow ever-finer levels of disaggregation and control. Nevertheless, while the costs of organising across long distances have fallen, the value of physical proximity for complex activity remains high, especially for building relationships, exchanging codified information and observing others (Glaeser, 2011). A number of studies have highlighted tools such as project-based organising (Grabher, 2002), virtual communities (Grabher and Ibert, 2014) and online tools (Bathelt, 2005) to mimic face-to-face interaction. In general, technology companies *both* make extensive use of these distance-based tools *and* tightly cluster into urban space (Nathan and Vandore, 2014; Martins, 2015).

How these local and non-local organising dynamics work in the Swedish case is an empirical question. In practice, we can observe co-location straightforwardly through structured data; firm–firm links and relationships are less easy to see.

8.2.3 The Swedish context

Sweden has a deep history of involvement in ICT production, especially electronic engineering, as well as closely related fields in advanced manufacturing (Giertz et al., 2015a, 2015b, from which this account draws heavily). Sweden industrialised late compared to its European rivals, but then developed very rapidly, particularly in telecoms: by 1855, for example, there were 5,000 telephone sets in Stockholm, the highest in the world at that time.

In the first half of the twentieth century, Sweden's ICT and manufacturing industries developed through a corporatist national policy framework, with private companies and the state co-creating key technologies and infrastructure, acting as developer and lead customer respectively. Some of these industrial policy bets worked out better than others: the Swedish personal computer industry faded away in the 1980s, for example, but the mobile communications industry did better. By 1969, a common Nordic mobile system had been developed; by 1985, Nordic Mobile Telephony (NMT) was the world's largest mobile network. The pan-European GSM standards group was formed in 1982, with Swedish companies heavily involved in developing the standard for its eventual launch in 1991; it subsequently became a global benchmark for telecoms, helping establish Ericsson as a global ICT player.

The corporatist policy framework, already under political attack in the 1970s and 1980s, was rolled back substantively during the 1990s after a fiscal crisis, when a number of pro-competition and pro-entrepreneurship policies were also introduced. In 1995 Sweden joined the European Community and deregulated energy, telecoms, postal services and the media, further altering its nationalised/corporatist economic development model.

The early 2000s saw Ericsson, the country's largest ICT firm, enter a period of crisis, driven by the dotcom crash and strategic miscalculations in 3G technology. By 2004, it had shed around half its workforce, with large job losses in Sweden. These company-level shifts had important knock-on effects in the country. Many laid-off engineers moved into hardware engineering, finance or banking, triggering a wave of entrepreneurship across ICT, especially software and the Internet.

In parallel, national level policy makers in Sweden introduced a number of measures to support new firm formation in the technology sector and other sectors. A policy consensus gradually grew on the need to raise levels of entrepreneurship in the country, especially in high-value activities. A number of subsequent reforms in the 1990s and 2000s – to tax and competition policy, for example – appear to have helped develop the country's entrepreneurship culture (Semuels, 2017). A national programme also provided subsidised PCs for households, with employers sharing costs; this widely diffused computers into society, including to households that otherwise would have been unable to afford them. Vinnova, the national innovation systems agency, was founded in 2001, as part of a major reorganisation of national economic development institutions. It takes a major interest in Industry 4.0, aiming to connect traditional industries to new digital processes and tools, especially in export industries.

8.3 Methodology

Our quantitative analysis uses microdata from the Statistics Sweden MONA database for the years 2007–2012 inclusive. We build industry and municipality-level panels from firm and worker-level microdata. The industry-level panel consists of 3,583 4-digit industry*year observations for 2007–2012. The municipality-level panel consists of 1,752 area*year observations for the same time period. Further details of the build are available on request.

To identify the set of tech firms that are Industry 4.0 producers, we start with a set of 'science and tech' industries drawn from an international benchmarking exercise conducted by the UK Office of National Statistics (Harris, 2015) and defined using 5-digit SICs. Drawing on the framework above, we refine this to proxy 'Industry 4.0' producer sectors, dropping a number of content activities (publishing, media, music, advertising) and science/health activities (life sciences, health), except where SIC descriptors directly pertain to R&D and/or manufacturing. We then crosswalk this to 4-digit SICs, which is identical to the NACE Rev 2 /SNI07 codes used in Sweden and other EU Member States.

We also select a set of STEM occupations from NESTA (Bakhshi et al., 2015), crosswalking these from UK SOC2010 occupation codes to SOC2008, then to the international ISCO08 and ISCO88 standards. The latter is identical to the SSYK-96 codes used in the Swedish data. Final lists of industries and occupations are given in the appendix, in Tables A1 and A2 respectively.

8.4 Results

Table 8.1 compares mean characteristics for the set of Industry 4.0 producing industries against the rest of the economy, pooled across the period 2007–2012. The right-hand column gives the result of a two-tailed T-test on means. We compare across a range of key characteristics in Panels 1 and 2. We can see that in almost all key characteristics, including workforce mix, these industries differ from the rest-of-industry average. Notably, while these industries produce substantively more patents than the rest of Sweden (covering over 75% of all Swedish patenting – see Table 8.2), and generate substantively higher exports, overall value added and turnover are not significantly different from other Swedish industries. This provides some support to the notion of the Swedish

Table 8.1 Industry 4.0 producers in Sweden: distinctiveness

Variable	*I4.0*	*Rest*	*Different?*
Total firms 5 years old or less	273,221	420,884	Y
Total large firms	2,161	1,628	Y
Total SMEs	882,073	1,582,661	Y
Total value added (mSEK)	3,579,333	3,211,102	N
Total net turnover (mSEK)	13,017,630	11,681,930	N
Total exports value (mSEK)	4,181,818	1,694,266	Y
Total patents weighted by applicants	13,830	3,012	Y
Total employment	4,395,439	4,209,906	N
Number of tertiary educated employees ≤ 3 yrs	826,717	636,933	Y
Number of tertiary educated employees > 3 yrs	1,396,159	783,519	Y
Total STEM workers	954,285	250,847	Y
Average science workforce intensity	0.013	0.010	Y
Average engineering workforce intensity	0.015	0.006	Y
Average tech workforce intensity	0.037	0.013	Y
Average stem workforce intensity	0.065	0.029	Y

Source: Statistics Sweden.

Notes: Graduates are those with 3 years or less tertiary education; + postgrads adds in those with more than 3 years tertiary education; STEM occupations defined from NESTA (2015); intensity = share of workers in science/engineering/tech/stem occupations, compared to all workers in these industries; tech industries defined using Harris (2015); turnover, value, added, exports value given in mSEK; patents weighted by applicants. Difference = two-tailed t-test, 5% significance or better.

Paradox. We can also see that compared to non tech-industries, 'sci-tech' and Industry 4.0 production have significantly more large firms, fewer start-ups and fewer small and medium-sized enterprises (SMEs).

Importantly, in Panel 3 we compare on the basis of STEM workforce 'intensity' and its component parts. The concept of workforce intensity draws on the idea of 'creative intensity' widely used in creative economy analysis (Bakshi et al., 2015). This defines a set of 'creative occupations' and then looks at how 'intensively' these are used across different industries. For a given industry *i*, creative intensity is defined as the share of workers in creative occupations in industry *i* out of all workers in *i*. Here, we substitute creative occupations for scientists, engineers, tech workers and the aggregate set of STEM workers. Again, we can see that Swedish Industry 4.0 producers are distinctive from the rest of Swedish firms in their use of scientists, engineers and technical staff.

Table 8.2 shows the main characteristics of the Industry 4.0 production sectors and covers the period 2007–2012 inclusive.

The top panel looks at workforce characteristics, while the middle and bottom panels cover firm characteristics. For each panel, we show totals by year, percentage change over the period, and these sectors' share of activity across all workers/all firms accordingly. We can see that in 2012, these sectors employed around 18% of all workers (top panel). Skilled workers make up a disproportionate share of this (these industries employ 21.6% of all graduates and just under 30% of all workers with postgraduate qualifications). Not surprisingly, over two-thirds of the country's workers in STEM jobs are employed in these sectors. While these industries' overall workforce share has fallen slightly between 2007 and 2012, shares of skilled and STEM workers have risen, often substantially.

Industry 4.0 production comprises just under 10% of all firms in Sweden (middle panel). This set of industries has grown by 17% since 2007 and its composition has changed, with a big rise in SMEs and start-ups, but a fall in large firms (those with over 250 staff). Nevertheless, the sector still contributes over a fifth of all large firms in Sweden. In terms of broader economic performance (bottom panel), turnover, value added and exports are all on an upward trend – yet, strikingly, patenting, a key innovation measure, has fallen since 2007.

Our analysis resonates with that of Giertz et al. (2015a), who classify Swedish ICT firms into eight cross-sector verticals. However, they focus on a much narrower range of established ICT firms (2,700 companies that have over five employees) compared with our sample. Within this smaller set, the 'hardware components' and 'complete systems' 'verticals' (closely related industry sets organised around common technologies, products or services) comprise around 14% of firms and over 20% of all ICT sector staff (over 26,000 of 132,000 FTE in 2011, compared with 459,000 in our data).

As in our ICT-wide data, hardware activity is a mix of a few large incumbents, plus a long tail of SMEs. The complete systems' vertical is dominated by a few large incumbents, with under 200 firms in total, of which Ericsson accounts for over 70% of all employees. By contrast, the hardware components' vertical is

Table 8.2 Industry 4.0 producers in Sweden: time trends

	Workers	*Graduates*	*+ Postgrads*	*STEM workers*
2007	464,683	85,516	135,288	90,503
2008	476,401	86,365	141,980	97,519
2009	455,653	84,132	143,814	99,395
2010	445,812	85,646	147,129	100,925
2011	459,503	88,853	153,370	104,161
2012	462,679	89,493	156,603	107,742
% change 2007–12	*–0.43%*	*4.65%*	*15.76%*	*19.05%*
% all, 2012	*17.73%*	*21.62%*	*29.97%*	*67.02%*
	Firms	*Start-ups*	*SMEs*	*Large firms*
2007	87,425	27,923	86,726	238
2008	90,552	28,274	89,483	237
2009	92,683	28,439	91,395	225
2010	87,493	27,415	85,912	221
2011	101,718	30,102	100,265	218
2012	102,606	29,703	101,043	220
% change 2007–12	*17.36%*	*6.37%*	*16.51%*	*–7.56%*
% all, 2012	*9.68%*	*11.40%*	*9.67%*	*22.00%*
	Turnover	*Value added*	*Exports*	*Patents*
2007	390,990	1,394,861	443,986	1,767
2008	376,374	1,427,239	459,208	1,690
2009	319,548	1,191,571	356,198	1,504
2010	381,274	1,260,775	410,137	1,677
2011	400,075	1,465,458	495,151	1,518
2012	383,141	1,448,182	465,684	
% change 2007–12	*–2.01%*	*3.82%*	*4.89%*	*–14.04%**
% all, 2012	*19.57%*	*18.67%*	*45.57%*	*76.93%**

Source: Statistics Sweden.

Notes: Tech industries defined using Harris (2015); graduates are those with 3 years or less tertiary education; + postgrads adds in those with more than 3 years tertiary education; STEM occupations defined from NESTA (2015); start-ups defined as firms 5 years old or less; turnover, value, added, exports value given in mSEK; patents weighted by applicants.

* Change and national shares given for 2011.

dominated by SMEs, with around ten employees on average; the few large firms have only a few hundred staff. Many of these firms are 'contracting manufacturing'. Many of the newer firms are start-ups producing 'fibre optics, nanotech, power electronics, printed electronics, control equipment, measuring and calibration, antennas, power transistors, alarms, lasers, sensors and actuators', and many are connected to universities.

The other hardware-relevant component of the Swedish ICT industry is R&D-focused consulting, which in Giertz et al. (2015a) comprised over 360 established firms and almost 12,400 staff in 2011. These firms work with other tech businesses on 'pure technical applications', including an important sub-set dealing with embedded systems and the Internet of Things. The roots of this consulting sector lie largely in corporate shake-ups, as discussed above.

8.4.1 Municipality analysis

Swedish Industry 4.0 producers are highly clustered, with Stockholm City and County the largest agglomeration of activity. Tables 8.3 and 8.4 give counts, shares and location quotients at municipality level for the years 2007–2012.

Table 8.3 looks at the 20 municipalities with the largest counts of Industry 4.0 firms. Over a quarter of these are in Stockholm County, with Stockholm Municipality having over twice as many firms as the next municipality (Gothenberg), over three times as many Industry 4.0 producer SMEs and around twice as many employees in these industries. Notably, tech SMEs make up almost all of the population of ICT firms and 9–18% of all SMEs in these municipalities. Stockholm County comprises around 47% of all Industry 4.0 employment in the 20 most ICT firm-dense municipalities.

Counts and shares do not fully control for the underlying economic structure of areas. Table 8.4 uses location quotients (LQs) to do this for the 20 municipalities with the highest LQs in 2007–2012. Lund has the highest LQ in Sweden in this period; Stockholm city has a rather lower LQ, reflecting its greater economic diversity. However, Stockholm County dominates the table: just under two-thirds of the Sweden's largest tech clusters are in Stockholm municipalities.

Other studies confirm this spatial picture. Chaminade et al. (2010) point to the Kista cluster of large tech MNEs (including Infosys, Huawei and Lenovo) just outside Stockholm city, as nationally important, alongside Skåne County (for computer games) and Linköping (for web servers). Over half the ICT employment identified by Giertz et al. (2015a) is located in Stockholm County[1] – over 60,000 FTE staff, far fewer than in Table 8.3 given the very restrictive sampling frame of those authors. Six of the eight verticals identified have over half their employees in the area. In hardware systems, Giertz et al. (2015a) highlight the fact that Ericsson has always been critically important to the Stockholm cluster – both through its location in Kista and elsewhere in the metropolitan area, and through its system-wide effects across the county and the country as a whole. Notably, the two *least*-concentrated sectors identified by Giertz et al. (ibid) are the focus of interest in this study. Around 77% of hardware components staff work outside Stockholm County, as do 65% of R&D-related consultancy staff. However, Stockholm remains the single largest location for these activities.

8.5 Conclusions

This chapter uses rich microdata to explore Industry 4.0 production in Sweden, a country with both a rich heritage in advanced manufacturing and an activist public policy tradition. Hardware products and services in Sweden can

Table 8.3 Firms and workers, top 20 Swedish municipalities by firm counts, 2007–2012

Code	*Municipality*	*County*	*Sci-tech firms*		*Sci-tech SMEs*			*Sci-tech workers*	
			Total	*% all firms*	*Total*	*% all SMEs*	*% all tech*	*Total*	*% all workers*
0180	Stockholm	Stockholm	17,176	13.84	17,114	14.04	99.64	121,529	17.32
1480	Gothenberg	Västra Götaland	6,881	14.32	6,853	14.51	99.59	64,989	32.93
1280	Malmö	Skåne	3,096	12.22	3,091	12.46	99.84	12,496	14.21
0380	Uppsala	Uppsala	2,353	13.43	2,351	13.64	99.92	6,932	21.19
1281	Lund	Skåne	1,854	17.90	1,850	18.12	99.78	11,685	41.25
0580	Linköping	Östergötland	1,531	13.83	1,529	14.09	99.87	13,039	42.65
1980	Västerås	Västmanland	1,337	14.11	1,332	14.31	99.63	15,099	41.55
0182	Nacka	Stockholm	1,281	13.82	1,279	14.03	99.84	2,544	19.59
1283	Helsingborg	Skåne	1,231	10.84	1,230	11.05	99.92	4,202	12.77
0160	Täby	Stockholm	1,214	16.95	1,214	17.23	100.00	1,978	14.70
2480	Umeå	Västerbotten	1,030	9.60	1,029	9.70	99.90	2,042	10.83
0184	Solna	Stockholm	1,026	15.74	1,022	16.02	99.61	4,946	6.19
0163	Sollentuna	Stockholm	1,014	17.35	1,014	17.63	100.00	1,855	11.13
0680	Jönköping	Jönköping	984	9.28	979	9.40	99.49	6,291	22.05
0581	Norrköping	Östergötland	948	10.52	946	10.70	99.79	2,908	10.33
1880	Örebro	Örebro	889	8.50	888	8.64	99.89	3,557	10.67
1384	Kungsbacka	Halland	888	11.43	887	11.59	99.89	1,146	12.19
0126	Huddinge	Stockholm	878	12.14	878	12.33	100.00	874	7.42
1490	Borås	Västra Götaland	797	9.01	795	9.12	99.75	4,040	17.25
1780	Karlstad	Värmland	783	9.92	782	10.07	99.87	2,384	13.57

Source: Statistics Sweden.

Notes: Tech industries defined using Harris (2015); start-ups defined as firms 5 years old or less.

Table 8.4 Location quotients, top 20 Swedish municipalities by firm counts, 2007–2012

Code	*Municipality*	*County*	*Firms*	*SMEs*	*Startups*	*Employees*
1281	Lund	Skåne	1.856	10.370	10.187	2.256
0163	Sollentuna	Stockholm	1.802	10.385	10.954	0.608
0160	Täby	Stockholm	1.758	10.386	10.395	0.802
0184	Solna	Stockholm	1.632	10.349	10.447	0.346
1262	Lomma	Skåne	1.603	10.392	9.925	0.984
1481	Mölndal	Västra Götaland	1.601	10.378	9.214	1.054
0183	Sundbyberg	Stockholm	1.571	10.377	11.006	0.688
0123	Järfälla	Stockholm	1.561	10.384	10.796	0.854
1402	Partille	Västra Götaland	1.507	10.392	9.647	0.693
0186	Lidingö	Stockholm	1.485	10.366	10.224	1.588
1480	Göteborg	Västra Götaland	1.484	10.349	10.554	1.793
0162	Danderyd	Stockholm	1.467	10.366	10.025	0.949
1980	Västerås	Västmanland	1.462	10.356	11.426	2.264
0180	Stockholm	Stockholm	1.435	10.354	10.836	0.944
0580	Linköping	Östergötland	1.433	10.375	10.489	2.324
0187	Vaxholm	Stockholm	1.432	10.392	10.923	0.532
0182	Nacka	Stockholm	1.432	10.382	10.687	1.067
0199			1.415	10.392	16.330	0.934
0117	Österåker	Stockholm	1.410	10.392	10.343	0.578
0128	Salem	Stockholm	1.403	10.392	10.122	0.382

Source: Statistics Sweden.

Notes: Tech industries defined using ONS/Harris (2015); start-ups defined as firms 5 years old or less.

draw on existing ecosystems, especially in electrical engineering and mobile communications. Swedish Industry 4.0 producers comprised around 10% of the country's firms in 2012, but around 20% of all large firms. They employed around 18% of all workers, but two-thirds of the country's STEM workers. These industries are nationally distinctive in their intensive use of skilled and STEM staff, high levels of patenting, turnover and exports. This setting presents both opportunities and challenges for Sweden as it develops readiness for Industry 4.0 (Nathan, 2018). Industry 4.0 producers can draw on a rich, perhaps unique, ecosystem of high-value knowledge, a web of potential suppliers and large numbers of skilled, experienced workers, much of which is already co-located in a few urban hubs. Unlike competitors such as Germany, in Sweden these industries are also dominated by a few large firms: there are relatively few start-ups and SMEs, although, as we have shown, their numbers are growing rapidly. Large incumbents are a striking feature of the Swedish ecosystem. They can act as key buyers of new products and services, and potentially partners in product/firm development. Historically, corporate shocks to large players – notably Ericsson – have helped feed subsequent growth in new entrants. Conversely, large firms in Sweden have tended towards incremental innovation conducted internally, which may present coordination problems for joint ventures. On top of policies to promote entrepreneurship and the growth of Stockholm as a leading European tech cluster, this suggests that future Swedish industrial policy will also need to look for tools to promote better links between emerging and existing industry actors in the national ecosystem.

Appendix

Table A1 List of sci-tech industries 'Science and tech' industries are drawn from an international benchmarking exercise conducted by the UK Office of National Statistics (Harris, 2015)

NACE	*NACE_descriptor*	*ONS_category*
1920	Mineral oil refining	other science_tech manufacture
2000	Manufacture of chemicals and chemical products	other science_tech manufacture
2010	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	other science_tech manufacture
2011	Manufacture of industrial gases	other science_tech manufacture
2012	Manufacture of dyes and pigments	other science_tech manufacture
2013	Manufacture of other inorganic basic chemicals	other science_tech manufacture
2014	Manufacture of other organic basic chemicals	other science_tech manufacture
2015	Manufacture of fertilisers and nitrogen compounds	other science_tech manufacture
2016	Manufacture of plastics in primary forms	other science_tech manufacture
2017	Manufacture of synthetic rubber in primary forms	other science_tech manufacture
2020	Manufacture of pesticides and other agrochemical products	other science_tech manufacture
2030	Manufacture of paints, varnishes and similar coatings, mastics and sealants	other science_tech manufacture
2040	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	other science_tech manufacture
2041	Manufacture of cleaning and polishing preparations	other science_tech manufacture
2042	Manufacture of perfumes and toilet preparations	other science_tech manufacture
2050	Manufacture of other chemical products	other science_tech manufacture
2051	Manufacture of explosives	other science_tech manufacture

(*continued*)

Table A1 Cont.

NACE	*NACE_descriptor*	*ONS_category*
2052	Manufacture of glues	other science_tech manufacture
2053	Manufacture of essential oils	other science_tech manufacture
2059	Manufacture of other chemical products n.e.c.	other science_tech manufacture
2060	Manufacture of man-made fibres	other science_tech manufacture
2521	Manufacture of central heating radiators and boilers	other science_tech manufacture
2530	Manufacture of steam generators, except central heating hot water boilers	other science_tech manufacture
2540	Manufacture of weapons and ammunition	other science_tech manufacture
2610	Manufacture of electronic components and boards	digital technologies
2611	Manufacture of electronic components	digital technologies
2612	Manufacture of loaded electronic boards	digital technologies
2620	Manufacture of computers and peripheral equipment	digital technologies
2630	Manufacture of communication equipment (other than telegraph and telephone apparatus and equipment)	publishing and broadcasting
2640	Manufacture of consumer electronics	digital technologies
2651	Manufacture of non-electronic instruments and appliances for measuring, testing and navigation, except industrial process control equipment	other science_tech manufacture
2652	Manufacture of watches and clocks	other science_tech manufacture
2660	Manufacture of irradiation, electromedical and electrotherapeutic equipment	life science and healthcare
2670	Manufacture of photographic and cinematographic equipment	publishing and broadcasting
2680	Manufacture of magnetic and optical media	digital technologies
2700	Manufacture of electrical equipment	other science_tech manufacture
2710	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	other science_tech manufacture
2711	Manufacture of electric motors, generators and transformers	other science_tech manufacture
2712	Manufacture of electricity distribution and control apparatus	other science_tech manufacture
2720	Manufacture of batteries and accumulators	other science_tech manufacture
2730	Manufacture of wiring and wiring devices	other science_tech manufacture

Table A1 Cont.

NACE	*NACE_descriptor*	*ONS_category*
2731	Manufacture of fibre optic cables	other science_tech manufacture
2732	Manufacture of other electronic and electric wires and cables	other science_tech manufacture
2733	Manufacture of wiring devices	other science_tech manufacture
2740	Manufacture of electric lighting equipment	other science_tech manufacture
2750	Manufacture of domestic appliances	other science_tech manufacture
2751	Manufacture of electric domestic appliances	other science_tech manufacture
2752	Manufacture of non-electric domestic appliances	other science_tech manufacture
2790	Manufacture of other electrical equipment	other science_tech manufacture
2810	Manufacture of general purpose machinery	other science_tech manufacture
2811	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	other science_tech manufacture
2812	Manufacture of fluid power equipment	other science_tech manufacture
2813	Manufacture of compressors	other science_tech manufacture
2814	Manufacture of other taps and valves	other science_tech manufacture
2815	Manufacture of bearings, gears, gearing and driving elements	other science_tech manufacture
2821	Manufacture of ovens, furnaces and furnace burners	other science_tech manufacture
2822	Manufacture of lifting and handling equipment	other science_tech manufacture
2823	Manufacture of office machinery and equipment (except computers and peripheral equipment)	other science_tech manufacture
2824	Manufacture of power-driven hand tools	other science_tech manufacture
2825	Manufacture of non-domestic cooling and ventilation equipment	other science_tech manufacture
2829	Manufacture of other general-purpose machinery n.e.c.	other science_tech manufacture
2830	Manufacture of agricultural and forestry machinery	other science_tech manufacture
2840	Manufacture of metal forming machinery and machine tools	other science_tech manufacture
2841	Manufacture of metal forming machinery	other science_tech manufacture
2849	Manufacture of other machine tools	other science_tech manufacture

(*continued*)

Table A1 Cont.

NACE	*NACE_descriptor*	*ONS_category*
2890	Manufacture of other special-purpose machinery	other science_tech manufacture
2891	Manufacture of machinery for metallurgy	other science_tech manufacture
2892	Manufacture of machinery for mining, quarrying and construction	other science_tech manufacture
2893	Manufacture of machinery for food, beverage and tobacco processing	other science_tech manufacture
2894	Manufacture of machinery for textile, apparel and leather production	other science_tech manufacture
2895	Manufacture of machinery for paper and paperboard production	other science_tech manufacture
2896	Manufacture of plastics and rubber machinery	other science_tech manufacture
2899	Manufacture of other special-purpose machinery n.e.c.	other science_tech manufacture
2900	Manufacture of motor vehicles, trailers and semi-trailers	other science_tech manufacture
2910	Manufacture of motor vehicles	other science_tech manufacture
2920	Manufacture of bodies (coachwork) for motor vehicles (except caravans)	other science_tech manufacture
2930	Manufacture of parts and accessories for motor vehicles	other science_tech manufacture
2931	Manufacture of electrical and electronic equipment for motor vehicles	other science_tech manufacture
2932	Manufacture of other parts and accessories for motor vehicles	other science_tech manufacture
3000	Manufacture of other transport equipment	other science_tech manufacture
3010	Building of ships and boats	other science_tech manufacture
3011	Building of ships and floating structures	other science_tech manufacture
3012	Building of pleasure and sporting boats	other science_tech manufacture
3020	Manufacture of railway locomotives and rolling stock	other science_tech manufacture
3030	Manufacture of air and spacecraft and related machinery	other science_tech manufacture
3040	Manufacture of military fighting vehicles	other science_tech manufacture
3090	Manufacture of transport equipment n.e.c.	other science_tech manufacture
3091	Manufacture of motorcycles	other science_tech manufacture
3092	Manufacture of bicycles and invalid carriages	other science_tech manufacture

Table A1 Cont.

NACE	*NACE_descriptor*	*ONS_category*
3099	Manufacture of other transport equipment n.e.c.	other science_tech manufacture
3212	Manufacture of jewellery and related articles	other science_tech manufacture
3240	Manufacture of professional and arcade games and toys	other science_tech manufacture
3250	Manufacture of medical and dental instruments and supplies	life science and healthcare
3312	Repair of machinery	other science_tech manufacture
3313	Repair of electronic and optical equipment	digital technologies
3314	Repair of electrical equipment	other science_tech manufacture
3315	Repair and maintenance of ships and boats	other science_tech manufacture
3316	Repair and maintenance of aircraft and spacecraft	other science_tech manufacture
3317	Repair and maintenance of other transport equipment	other science_tech manufacture
5100	Air transport	other science_tech services
5110	Scheduled passenger air transport	other science_tech services
5120	Freight air transport and space transport	other science_tech services
5121	Freight air transport	other science_tech services
5122	Space transport	other science_tech services
5820	Software publishing	digital technologies
5821	Publishing of computer games	digital technologies
5829	Other software publishing	digital technologies
6200	Computer programming, consultancy and related activities	digital technologies
6201	Computer programming activities	digital technologies
6202	Computer consultancy activities	digital technologies
6203	Computer facilities management activities	digital technologies
6209	Other information technology and computed service activities	digital technologies
6310	Data processing, hosting and related activities; web portals	digital technologies

(*continued*)

Table A1 Cont.

NACE	*NACE_descriptor*	*ONS_category*
6311	Data processing, hosting and related activities	digital technologies
6312	Web portals	digital technologies
7100	Architectural and engineering activities; technical testing and analysis	other science_tech services
7110	Architectural and engineering activities and related technical consultancy	other science_tech services
7111	Architectural activities	other science_tech services
7112	Engineering activities and related technical consultancy	other science_tech services
7120	Technical testing and analysis	other science_tech services
7219	Other research and experimental development on natural sciences and engineering	other science_tech services
7220	Research and experimental development on social sciences and humanities	other science_tech services
7490	Quantity surveying activities	other science_tech services
8540	Higher education	other science_tech services
8541	Post-secondary non-tertiary education	other science_tech services
8542	Tertiary education	other science_tech services
9511	Repair of computers and peripheral equipment	digital technologies
9521	Repair of consumer electronics	other science_tech manufacture
9522	Repair of household appliances and home and garden equipment	other science_tech manufacture
9525	Repair of watches, clocks and jewellery	other science_tech manufacture

Note: The ONS set of industries is defined at 5- digit SIC2007 level. I refine this to focus on Industry 4.0, dropping a number of content activities (publishing, media, music, advertising) and science / health activities (life sciences, health), except where SIC descriptors directly pertain to R&D and/ or manufacturing. We then crosswalk this to 4- digit SIC, which is identical to the NACE Rev 2 / SNI07 codes used in Sweden and other EU states.

Table A2 List of STEM occupations STEM occupations are taken from NESTA (Bakhshi et al., 2015)

Category	*ISCO88*	*ISCO88_descriptor*
IT	1226	Production and Operations Department Managers in Transport, Storage and Communications
IT	1236	Computing Services Department Managers
IT	1316	General Managers in Transport, Storage and Communications
IT	1317	General Managers of Business Services
Science	2113	Chemists
Science	2211	Biologists, Botanists, Zoologists and Related Professionals
Science	2212	Pharmacologists, Pathologists and Related Professionals
Science	2111	Physicists and Astronomers
Science	2114	Geologists and Geophysicists
Science	2211	Biologists, Botanists, Zoologists and Related Professionals
Science	2212	Pharmacologists, Pathologists and Related Professionals
Engineering	2142	Civil Engineers
Engineering	2144	Mechanical Engineers
Engineering	2143	Electrical Engineers
Engineering	2144	Electronics and Telecommunications Engineers
Engineering	2149	Architects, Engineers and Related Professionals Not Elsewhere Classified
Engineering	2149	Architects, Engineers and Related Professionals NEC
Engineering	2150	Architects, Engineers and Related Professionals NEC
IT	2131	Computer Systems Designers and Analysts
IT	2132	Computer Programmers
IT	2139	Computing Professionals NEC
IT	2131	Computer Systems Designers and Analysts
IT	2132	Computer Systems Designers and Analysts
IT	2131	Computer Systems Designers and Analysts
IT	2132	Computer Programmers
IT	2139	Computing Professionals NEC
IT	2131	Computer Systems Designers and Analysts
IT	2132	Computer Programmers
IT	2139	Computing Professionals NEC
Science	2211	Biologists, Botanists, Zoologists and Related Professionals
Science	2212	Biologists, Botanists, Zoologists and Related Professionals
Science	1237	Research and Development Department Managers
Science	1319	General Managers NEC
Engineering	2148	Cartographers and Surveyors

Note: I crosswalk these from UK SOC2010 occupation codes to SOC2008, then to the international ISCO08 and ISCO88 standards. The latter is identical to the SSYK-96 codes used in the Swedish data.

Note

1 Stockholm County consists of 26 municipalities, out of 290 municipalities, and there are 20 counties in the whole of Sweden.

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9 De-globalisation, value chains and reshoring

Diletta Pegoraro, Lisa De Propris and Agnieska Chidlow

9.1 Introduction

This chapter aims to review the recent debate on de-globalisation and to present some preliminary evidence that reconsiders the value of a manufacturing activity in light of the current geopolitical turmoil and new technological availabilities (*The Economist*, 2009). This is somehow important as changes in the nature of markets and technology can significantly impact on firms' location decisions in relation to manufacturing activities (Chidlow et al., 2009; Chidlow et al., 2015; Li and Bathelt, 2018; Mudambi et al., 2018). More specifically, such location decisions can relate to the adaptation of a reshoring strategy, which involves bringing manufacturing production (or part of it) back from abroad.

Since the 1970s, the intensification of exchanges in trade, capital and knowledge has fostered the inter-connectedness of economies on a global scale. Pushed by a neoliberal rationale, Western companies started expanding part of their business functions, *in primis* production and manufacturing, beyond their national borders. This was operationalised in two ways: either by relocating production facilities to a foreign location (in-house offshoring); or by outsourcing some functions to foreign suppliers (outsourcing offshoring). These strategies required production and manufacturing processes to be sliced up into smaller segments and to be coordinated by the lead firm (Jabbour, 2012; Timmer et al., 2014). In the 1990s, the global value chains (GVCs) framework was used to describe the increasing adoption of this fragmented production model by MNEs (Benito et al., 2019; Gereffi and Korzeniewicz, 1994). Since then, the GVC framework has been widely adopted by international organisations such as the Organisation for Economic Co-operation and Development (OECD), the World Trade Organization (WTO) and the United Nations Conference on Trade and Development (UNCTAD) to monitor the impact of this global organisation of production on host (and less so on home) economies, as well as on trends in globalisation and international trade. Many studies have looked at how countries were involved in GVCs through backward and forward linkages[1] and the impact of this involvement on their socio-economic development (Baldwin, 2016; Los et al., 2015; Timmer et al., 2014; Wang et al., 2017). In hindsight, the end of the 1990s and the beginning of the 2000s marked a time when globalisation and pro-globalisation forces peaked.

The global organisation of production in GVCs started to be challenged by the Global Financial Crisis (GFC) in 2008/2009 and following the collapse of the so-called Washington Consensus (Gereffi, 2014). The GFC brought to the fore not only the cost of having economies inter-linked and therefore at risk of shocks initiated elsewhere, but more crucially, it also highlighted the socio-economic cost of offshoring on home economies. The outcome has been a more critical approach to globalisation as businesses have also started to weigh the costs and benefits of coordinating worldwide production processes with changing markets and emerging new technologies. The current reconfiguration of GVCs is also led by geopolitical and trade forces, which this chapter only tangentially touches upon.

9.2 The world got smaller

The concept of modern globalisation is very recent. It was first introduced by the seminal work of Levitt (1983) for describing the novel phenomenon on the globalisation of markets. Since then, a large literature has flourished to try to define the concept and to identify key actors, drivers and operations, as well as discussing its benefits and costs and for whom.[2] The globalisation of markets was only the tip of the iceberg; however, the comfort of operating in a mature technological paradigm meant more aggressive price competition in domestic and international markets, forcing firms to seek cost reduction in production. At the same time, faster transport and easier communications really made the world a smaller place. In this context, multi-national enterprises (hereafter MNEs) saw the opportunity to extend their reach to markets that were global but fundamentally homogeneous, giving them scope to benefit from significant economies of scale (Baldwin, 2016).

Technology and the nature of competition constantly change the way in which the economy organises production and especially in the manufacturing sectors. The organisation of production had already moved away from the vertically integrated Fordist model (Chandler, 1962) to a stage-specialised and vertically dis-integrated flexible specialisation model from the 1960s onwards (Piore and Sabel, 1986). Networks of buyers and sellers replaced the factory model, as large firms became core buyers coordinating such networks (Saxenian, 1990). More generally, smaller and more specialised firms became parts of flexible and ever adjustable networks of buyers and suppliers located geographically closer to each other, thereby fostering agglomeration and external economies (Becattini, 1990 and Becattini et al., 2014; Porter, 1996), as well as flexibility, specialisation and innovativeness. These local production systems responded to a volatile and sophisticated demand eager for differentiated, innovative and fast-changing products. The introduction of new technologies such as electronics and mechatronics (with the transistor and microprocessor), as well as easily accessible telecommunications and computers since the 1960s allowed this reorganisation of production. The technological changes described above are often referred to as being part of the Third Industrial Revolution (see Chapter 1 in this volume).

Production processes that were already disintegrated and parcelled underwent another radical reorganisation from the 1980s onwards. Globalisation kicked in and firms, especially large buyers seeking cost efficiency to compete in global markets, started to move labour-intensive functions to lower labour-cost countries in Asia and China in particular. Indeed, this could not have taken place without the concomitant opening of China and Asia to the global economy as an attractive location to produce to export. The location decision choice of MNEs in relation to different portions of the supply chain created worldwide and complex global value chains (, Dicken, 2015; Feenstra, 1998; Gereffi, 1999; Krugman et al., 1995). Indeed, each stage of the production process was associated with varying degrees of value creation to which different costs were apportioned. Low and high-value added functions were geographically separated and for the first time the production process was unbundled (Baldwin, 2016), i.e. geographically dispersed contributing to an international fragmentation of production. Indeed, low-value-added functions were located in developing and emerging economies to benefit from raw materials or lower labour costs. In contrast, high-value-added functions (high-end design, R&D and product development) largely remained anchored in high-cost and high knowledge-intensive locations (Mudambi, 2007).

For decades, the operations of global value chains through 'offshoring' and foreign direct investment have redesigned the architecture of manufacturing activities worldwide. This created a thick web of exchanges between the East and West and transformed the economic and social profile of places, reshaping their identities (Mudambi, 2008; Mudambi and Venzin, 2010; Storper and Scott, 1995). There has always been a strand in the international business literature suspicious of the uneven distribution of the benefits of globalisation (Bailey et al., 2010; Chomsky, 2016), but their arguments were sidelined by an overwhelming enthusiasm for and obsession with globalisation (by hyper-globalists). This zeal for globalisation came to an end in 2008 with the GFC.

9.3 The de-globalisation debate

Economies and societies face unprecedented changes every time a worldwide economic and political shock occurs. Recently, the 2008 GFC profoundly disturbed the status quo of advanced economies and their societies: firstly, it was followed by a deep and somewhat long economic recession across Europe and the US which left firms uncertain about accessing finance and therefore investments (Gereffi and Luo, 2014); secondly, austerity and unemployment led to the emergence of populist movements in Western countries, and, in the EU, to a resentment towards European tight fiscal policies (Rodrik, 2018a); finally, protectionist policies and a reduction of outward investment from advanced countries – especially to developing countries – has stalled globalisation as it was perceived before.

In addition to these three aspects, there is one more whose importance has increased recently: technological change. There is a wave of new technologies that is emerging and the expectation is that they will change production models, the nature of sectors, markets and the terms of trade (Galvin et al., 2018). Some large firms and MNEs have been first-movers and actually driving the whole narrative on digitalisation and automation, together with innovative micro-firms in these frontier technologies at the other end of the spectrum. The more substantial impact on the form of supply chains is still to come. There is evidence that MNEs are reorienting their internationalisation strategies by changing the parameters of their production location choices.

The fallout from the GFC and the emergence of new technologies has had the unexpected consequence of stalling globalisation as firms have reassessed the true benefits of internationalisation. As GVCs appear to be shrinking and international investments fall, the world seems to be becoming a smaller place (Baldwin, 2016). Indeed, in the last decade the aggressive pro-globalisation narrative has been replaced by a more pragmatic and balanced view which has exposed the weaknesses and the risks inherent in globalisation and global value chains (Bailey and De Propris, 2014a), leading to a long-overdue and more open debate on the heterogeneous effects of globalisation across places, industries, communities and people.

Policy makers and leading scholars have started to shift their attention from the benefits that globalisation delivered to MNEs in the form of offshoring large parts of their value chains, to the costs entire communities were left to pay economically and socially in hollowed-out home regions (Bailey and Turok, 2016). Indeed, a first consequence of globalisation was the relocation of labour-intensive manufacturing operations away from historical industrial regions in the US and Europe (and especially the UK), causing deep unemployment and contributing to increasing levels of inequality in advanced societies (Davis, 2013; Davis and Cobb, 2010). A second and more systemic concern with manufacturing hollowing-out was that it weakened the ability in the European and US economies to promptly respond to external shocks, such as the 2008 GFC. The demise of manufacturing activities resulted in a loss of skills, competences and tacit knowledge across a sufficiently diversified suite of sectors, reducing economic diversity and eroding systemic economic resilience. Such *malaise* led to a revived interest around manufacturing and what forms of manufacturing could be relocated in countries such as the US or the UK to 'rebalance' their economies (Ancarani et al., 2015; Bayley and De Propris, 2014b; Gray et al., 2013; Kinkel, 2014; Tate et al., 2014) Opportunities for repopulating manufacturing industries were explored by the EU Commission (EU Commission, 2014) and by the Obama administration (White House Administration, 2012).

This renewed interest in manufacturing initiated a reflection on what manufacturing really meant in the 2010s. The outcome of the relationship between technological changes and sustainability concerns flourished in a new competitive context. A fast-moving debate on an emerging new manufacturing model shaped by a range of new technologies (considered as part of the Fourth Industrial Revolution) triggered a process of profound production reorganisation which could also result in a reconfiguration of global value chains. The OECD suggests that the Fourth Industrial Revolution has the potential to restore the competitiveness of advanced economies (OECD, 2017). The ambition and vision by policy makers to strengthen the presence of manufacturing across EU regions or US states was received positively by businesses, which were themselves sensing a change in the wind. The running 'offshoring train' that lots of firms had jumped on now started to slow down.

This offshoring slowdown spurred a rethink of businesses' strategies towards more regional and arm's-length controlled operations (Bailey and De Propris, 2014b). This trend was also recorded by macro-economic indicators such as foreign direct investment (FDI) (see Section 9.3 for more details). Firms are not the only actors playing a role in reducing the intensity of globalisation; society as a whole is involved. Protests on climate change, air pollution, gas emissions, but also movements for better labour conditions in developing countries, are leading the phenomenon of de-globalisation. Society as a whole is becoming more interested in issues relating to the Sustainable Development Goals (SDGs) and following a path that diverges from the neoliberalism position which was dominant for more than three decades (Lawrence and Almas, 2018).

9.4 The reorganisation of global production

As social dynamics are changing, so too is the global production system. The role of technology is of primary importance in this transformation. At the 2019 World Economic Forum, economists and policy makers discussed issues relating to the theme of 'Globalisation 4.0: Shaping a New Architecture in the Age of the Fourth Industrial Revolution' (Schwab, 2018). Industry 4.0 and its technological development profoundly shape sectors such as health, mobility, services, finance and manufacturing. Especially in manufacturing, Industry 4.0 triggers changes in shortening the process of product development, and the identification of new markets, flexibility, organisational hierarchy and efficiency (Lasi et al., 2014). Heavy investments in technological development by advanced economies paid off in terms of offering new solutions in the realm of robotics and AI together with other digital technologies such as cloud computing, big data and the sharing economy. This wave of technological change is often referred to as the Fourth Industrial Revolution (Lasi et al., 2014).

This revolution started in the early 2010s and its exponential growth is influencing actors across society. The production process paradigm in particular is shifting from mass-production to mass-customised production as new production technologies open up the opportunity to reduce the impact of labour cost on the overall production costs (Brettel et al., 2014; Rodrik, 2018). In so doing, the decision to locate low-value and high-labour content tasks in low labour cost countries might no longer be a mainstream value chain strategy.

New technologies to engage in the production process are not the only factors which influence the boundaries of a global production process (Schotter et al., 2017; Strange and Zucchella, 2017); other factors can play a role as well. Firstly, developing countries are still competitive in term of labour wages, but the gap with advanced countries is narrowing and eroding the short-term cost benefit of locating a business function there (Tate et al., 2014). Secondly, China – once the factory of the world – is heavily investing in the high-technology (AI and robots) and infrastructure sectors (the One Belt One Road Initiative) to support and foster its internal economic and demographic growth (Swaine, 2015). In the 2000s, its goal was hosting different types of manufacturing sectors by offering investment incentives and tax reduction. In the 2020s, its focus is to become a leader in green and sustainable technology (Ju and Yu, 2018). Thirdly, rising South-South trade and consumption in the Global South will prompt a reorganisation of GVCs (Horner and Nadvi, 2018). Finally, there are political uncertainties pervading Western economies, such as a weak EU and the the US-China trade war (Inglhart and Norris, 2016). These exogenous factors of a macro-political scale have an important effect on the organisation of manufacturing processes in MNEs and small and medium-sized enterprises (SMEs).

Some of the tangible examples of this fragile and kaleidoscopic scenario are Brexit, steel tariffs in the US and the reorganisation of the automotive supply chain in Germany and the wider European automotive industry. The first effect could lead towards an increase in supply chain complexity, and transportation and logistics costs in the near future in the UK (*Financial Times*, 2018a, 2018b). The second effect is the possibility of bringing back production from abroad inside US borders or establishing a closer relationship with domestic or Mexican suppliers (*The Economist*, 2018). The third example concerns losing ground in the automotive industry, as electric cars start to gain momentum and the German (and European) automotive business model is highly oriented towards petrol and diesel cars (Bormann et al., 2018).

From this brief list of tangible examples, new opportunities are arising, and among these, there is a chance that advanced economies might host again manufacturing activities, which are becoming increasingly higher value added, albeit less labour intensive. (Vanchan et al., 2018). Manufacturing functions are becoming higher in value than before, as they are no longer the mere assembly part of the value chain, but part of an integrated process that feed from innovation and meet consumers' need with reduced lead-time. This requires access to a highly skilled labour force and technological capabilities which advanced economies have. This is what in part is driving the current de-globalisation wave.

Having recognised that de-globalisation is a broader social movement created by a discontent with globalisation, this chapter continues to explore de-globalisation with some data at the macro-level before introducing the concept of manufacturing reshoring.

9.5 Some evidence of de-globalisation

In this section we piece together evidence on de-globalisation by looking at three trends: 1) recent trends in FDI[3] in terms of volume, geography, sector and operations; 2) the current reorganisation of GVC into shorter and more compact value chains; and 3) current firms' strategies to reshore production functions back to the home economy. We will discuss each of these in turn.

9.5.1 FDI trends

In the last few years, outward and inward global FDI has stagnated partly due to a contraction in the *volume of outward FDI* from advanced economies and inward FDI to developing economies. Figures 9.1a and 9.1b below show that inward and outward global FDI peaked in 2007, before dropping dramatically afterwards in 2008–2009, especially from advanced economies, and has not recovered to pre-crisis levels (for more evidence, see UNCTAD, 2018, Figure 9.5, p. 10). The lack of growth in FDI return on investment (ROI) in developing and transition economies in the period 2016–2017 and the rise of investments in asset-light forms of production suggest that an international production reorganisation is under way, especially in terms of a regionalisation of FDI (UNCTAD, 2017, 2018).

There is also evidence of a *changing geography of FDI*. Looking at regional levels of FDI in the period 2016–2017, inward FDI fell by 69% in Europe and 65% in North America, contributing to a total drop in inward FDI of 59% in 2017 with respect to the previous year in advanced economies. In the same period, there was no variation in inward FDIs into developing economies, as East and South Asia recorded a slight increase of 2%, while a negative figure was registered for West Asia and Africa of 21% and 27% respectively. Latin America and the Caribbean performed well by attracting 8% more FDI in 2017 than in the previous year (Figure 9.2). Equally, outward FDI fell by \$800 billion, reaching \$1 trillion in 2017 (\$1.8 trillion in 2007). Outward FDI from advanced economies – despite a recovery in 2015 – in 2017 was still well below the pre-crisis level in 2007, especially in terms of European and US FDI. Overall these two trends negatively impacted on the global picture, as FDI from other parts of the world is not compensating in value (see Figure 9.3).

The changing geography of FDIs seems to occur at the same time as a shift in the sectors and modes of entry. By distinguishing FDI according to sector destination, Table 9.1 shows that overall, there has been an increase in Announced Greenfield FDIs in the manufacturing sector in 2017. Sector data show that advanced countries invested much less abroad in particular in the primary (raw materials), energy and services sectors. However, it is noticeable that advanced countries were the favourite destination for more FDI in manufacturing sectors (with a 34% increase); chemicals and chemical products, electrical and electronic equipment, and motor vehicles sectors are leading the trend in this regard. The bottom part of Table 9.1 shows data on the destinations

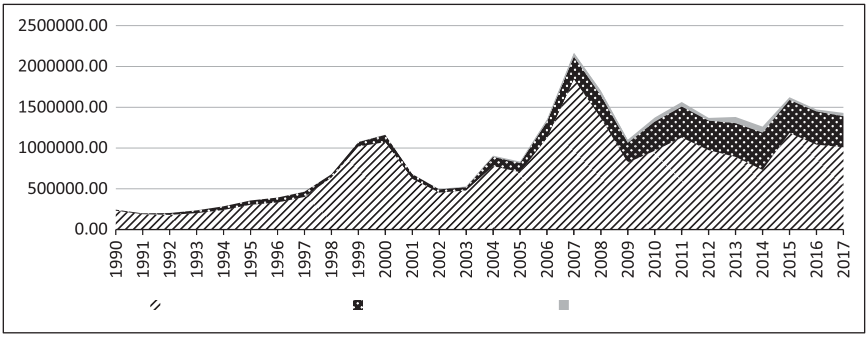

Figure 9.1a FDI outflows, 1990–2017.

Source: Authors' elaboration, based on UNCTAD (2018).

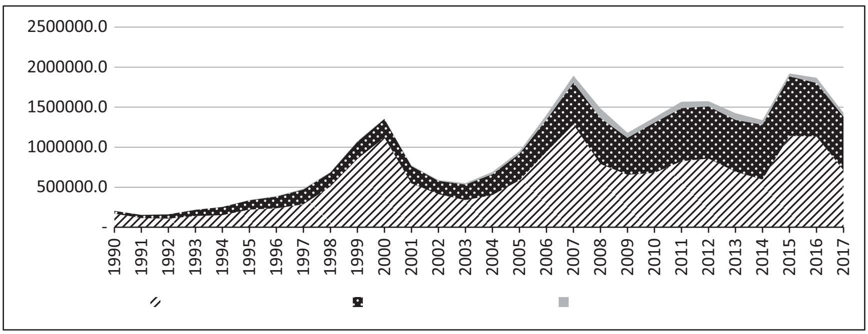

Figure 9.1b FDI inflows, 1990–2017.

Source: Authors' elaboration, based on UNCTAD (2018).

of greenfield FDI by macro-regions. Here we see more clearly that advanced countries have invested less in East and South Asia, South Asia and West Asia. Closer to home for the EU, FDI in transition economies in Eastern Europe has also dropped substantially. According to the data, advanced countries invested more in other advanced countries (i.e. US and Europe), with an increase of up to 32%. In other words, advanced countries are intensifying investments in other advanced countries and are reducing those in developing countries; this conforms with the view that de-globalisation is ongoing.

If we take a longer time horizon and look at the percentage of greenfield announcements between 2007 and 2017, both in value and number, we again find evidence of the changing patterns of FDI in support of a de-globalisation trend. By taking 2007 as a base year, Figure 9.4 shows that both the value and number of FDI projects to advanced economies increased, whilst those to

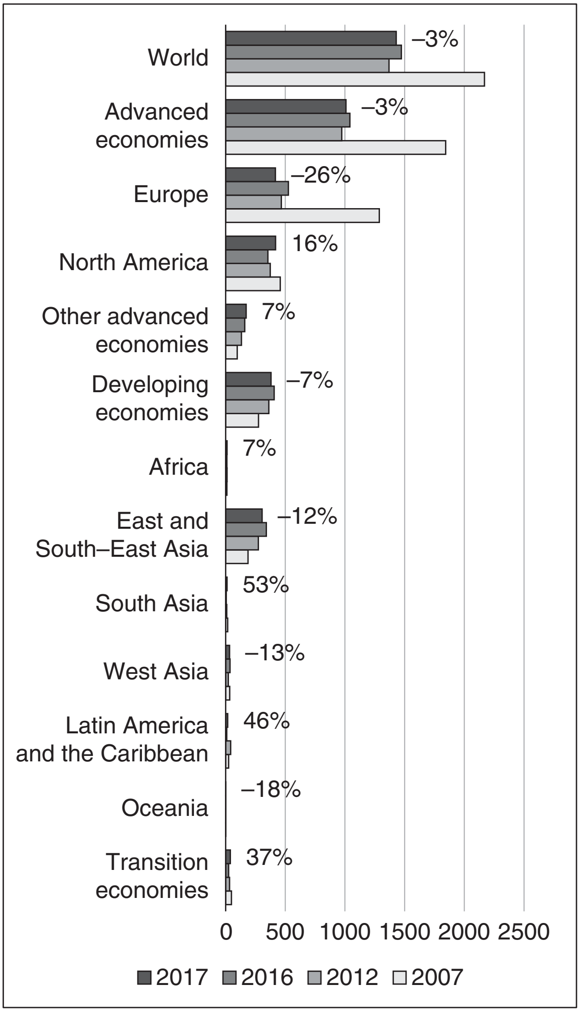

Figure 9.2 FDI outflows, by region and selected years (% variation 2016–2017).
Source: Authors' elaboration based on UNCTAD data (2018).

developing economies fell. In particular, the value of investments to advanced economies rose from 37% to 44%, while it fell from 55% to 51% to developing economies. However, it should be noted that in 2017, still half of the value of FDI was destined to developing economies. In terms of numbers, we observe similar patterns, but in 2017 a growing number of FDI projects were actually destined to advanced economies (58% of the total).

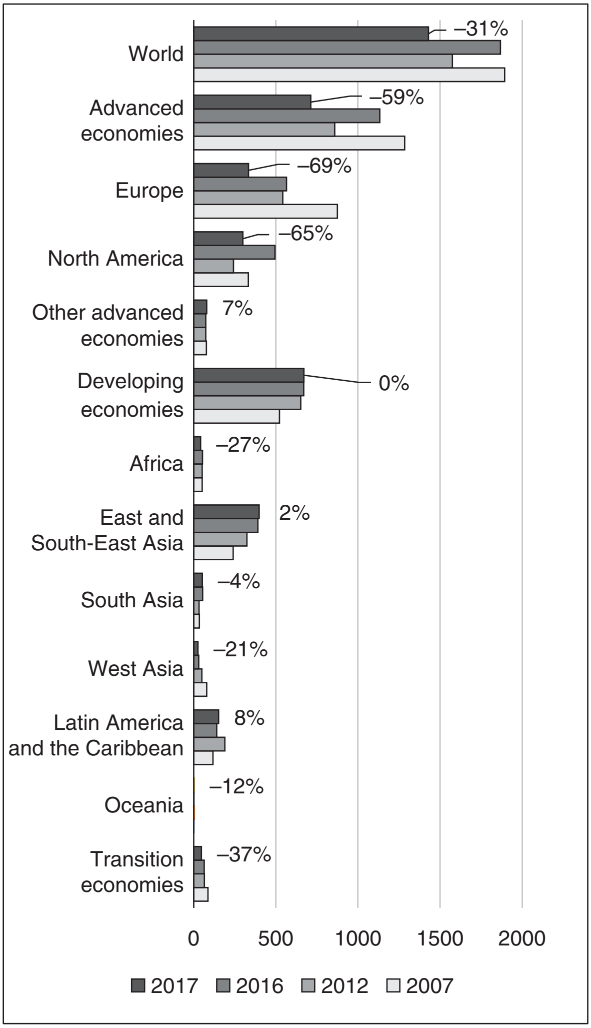

Figure 9.3 FDI inflows, by region and selected years, (% variation 2016–2017).
Source: Authors' elaboration with 2018 UNCTAD data.

Overall, the FDI data show that investment by advanced economies in Asia has contracted, whilst FDI flows within advanced economies have increased. The latter has involved in particular manufacturing sectors and some service sectors such as business services. This trend seems to suggest a change in the motives and destinations of foreign investments by MNEs from advanced economies.

Table 9.1 Announced greenfield FDI, 2016–2017

	Advanced countries as destination			*Advanced countries as investor*		
	2016	*2017*	*Var%*	*2016*	*2017*	*Var%*
Part I						
Total	254,187	318,406	20%	501,218	478,359	-5%
Primary	2,446	3,996	39%	47,371	18,415	-157%
Manufacturing	99,300	151,314	34%	197,404	212,357	7%
Textiles, clothing and leather	18,162	16,127	-13%	22,617	20,643	-10%
Chemicals and chemical products	12,813	32,060	60%	30,361	34,738	13%
Electrical and electronic equipment	8,161	21,669	62%	18,574	21,746	15%
Motor vehicles and other transport equipment	21,586	31,817	32%	44,561	47,555	6%
Services	152,441	163,096	7%	256,443	247,587	-4%
Electricity, gas and water	32,287	23,404	-38%	67,613	42,330	-60%
Construction	30,314	26,292	-15%	35,371	35,475	0%
Trade	15,823	20,967	25%	21,622	27,860	22%
Transport, storage and communication	15,498	12,954	-20%	31,220	32,356	4%
Business services	44,096	54650	19%	65,390	68,721	5%

Part II

Announced greenfield FDI projects by macro-region, 2016–2017 (millions of dollars)

	2016	*2017*	*Var%*	*2016*	*2017*	*Var%*
World	254,187	318406	20%	501,218	478,359	-5%
Advanced economies	204,031	255,003	20%	204,031	255,003	20%
Europe	127,061	150,934	16%	131,859	160,778	18%
North America	55,627	72,810	24%	54,370	70,537	23%
Other advanced countries	21,343	31,259	32%	17,802	23,687	25%
Developing economies	49,460	61,985	20%	242,827	204,501	-19%
Africa	1,411	1,961	28%	19,945	32,398	38%
East and South Asia	36,604	35,810	-2%	94,060	76,881	-22%
South Asia	6,759	5,986	-13%	46,873	23,479	-100%
West Asia	2,887	15,655	82%	23,159	13,579	-71%
Latin America and the Caribbean	1,799	2,572	30%	58,653	57,781	-2%
Transition economies	696	1,418	51%	54,360	18,855	-188%

Source: Authors' elaboration, based on UNCTAD (2018).

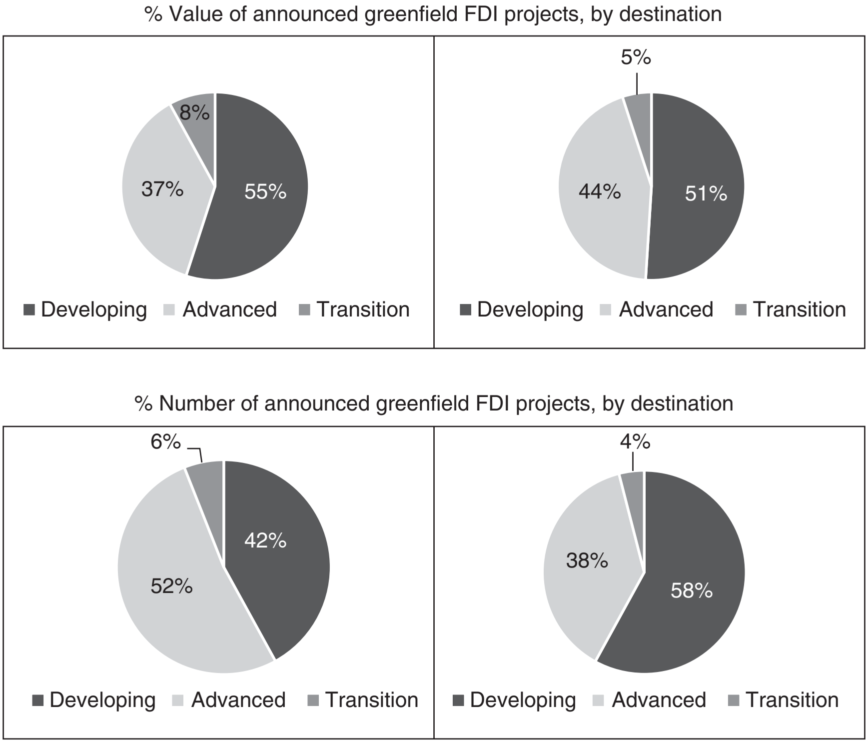

Figure 9.4 Number and value of greenfield FDIs, 2007 and 2017.
Source: Authors' elaboration, UNCTAD data (2018).

In parallel to the slowdown of worldwide FDIs flows, *geopolitical turmoil* also seems to weave a narrative around protectionism, trade wars and national interest. For long loud advocates of the free market, the US has recently embarked on a journey to curtail its trade in an effort to protect domestic jobs (White House, 2017).

According to UNTACD (2018), political factors and the emergence of strategic technologies will shape future FDI flows. Indeed, early moves by some political leaders in advanced economies to scrutinise FDI more closely can be seen as emerging signs of policy makers aiming to screen or block inward investment on public order and national security grounds. For example, the US Department of the Treasury introduced 'temporary regulations to protect critical American technology and intellectual property from potentially harmful foreign acquisitions' (US Treasury, 2018). Equally, tax reforms in the US that reward the repatriation of accumulated profits by American MNEs are aimed at cutting FDI outflows. In the EU, the International Trade Committee (INTA) proposed a harmonisation of FDI screening between Member States in order to cooperate over security and public order issues against emerging FDI inflows (EU Parliament, 2018).

Geopolitics and governments' concern with controlling emerging technologies are influencing the degree of openness to foreign investment and therefore countries' links in the GVC. Geopolitics is diffusing a sense of mistrust and uncertainty towards the motives of FDI, whereas protecting strategic technology explains countries' wariness to share knowledge and innovation. This seems to be less the case for exchanges within macro-regions such as Asia and Europe, suggesting a trend towards a regionalisation of investment activities.

9.5.2 Shorter and more compact value chains

FDI is not the only economic measure we can consider. Trade data gives us further insights on global economic trends and on the state of global production fragmentation, and hence on GVCs (Frederick, 2014).

The latest data (UNCTAD, 2017, 2018) provides significant evidence that EU GVCs are strongly integrated intra-EU; in particular, European GVCs in manufacturing are less integrated globally than expected: they have lower foreign sourcing percentage of intermediates (i.e. backward participation) and limited use of EU intermediates in exporting to non-EU countries (UNCTAD, 2018, p. 23). This is the culmination of trends that, since 2012, have seen EU firms sourcing more from within the EU, at the expense of extra-EU sourcing (see Figure 9.5). By extension, intra-regional exports of intermediate goods have risen within the EU and have dropped from outside the EU (see Figure 9.6).

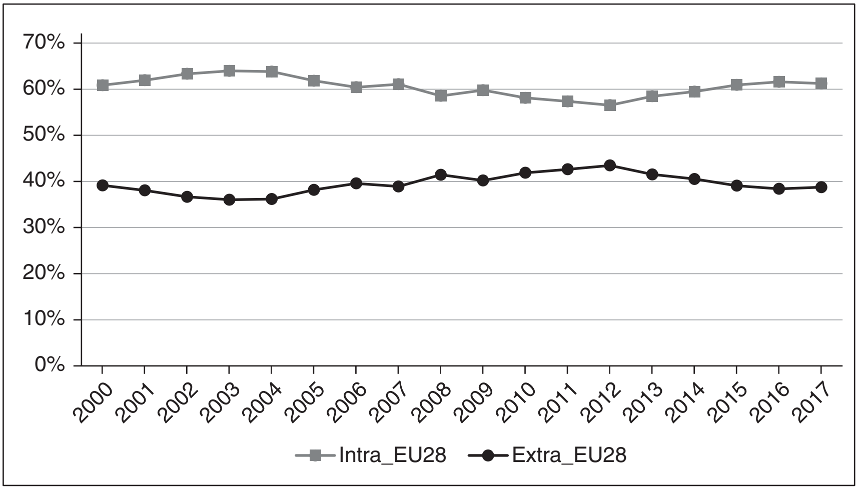

Figure 9.5 EU-28 intra-regional trade import in intermediate goods, 2000–2017 (% in regional total).

Source: Authors' elaboration with EUROSTAT data.

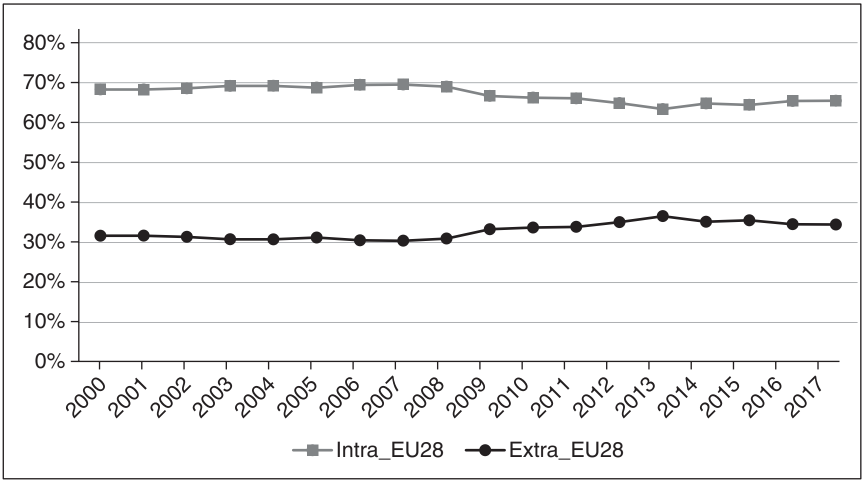

Figure 9.6 EU-28 intra-regional trade export in intermediate goods, 2000–2017 (% regional total).

Source: Authors' elaboration with EUROSTAT data.

Overall, the EU-28 presents a lower GVC participation rate (at 30%) than other economies (Backer and Miroudot, 2013).

This is consistent with UNCTAD (2018), which records a stagnation in the activities of post-2008 GVCs; in particular, the report found a change in the organisation of production of G7 economies (including the UK, Germany, France and Italy) between 2011 and 2015, with an increase in 'traditional trade production' (production to export) and a drop in 'simple GVCs' and 'complex GVCs'. The latter was particularly the case for manufacturing GVCs. Academic debate has started to observe such trends, suggesting that international production might be undergoing a structural reorganisation. Gereffi et al. (2014), for example, suggested that as assets became more intangible, firms required different skills and competencies, as well as adopted different internationalisation strategies by redrawing their value chain.

Another way of exposing changes in current patterns of production is to measure how much Foreign Value Added (FVA) is embodied in imports and exports. According to UNCTAD (2018), FVA measures how much of the value added produced originates from GVCs. It found that FVA peaked in 2010–2012 and that what appeared to be an adjustment post-crisis has now become structural. Indeed, UNCTAD (2018) reports FVA in imports falling year on year from 2015 to 2017, although the EU has a high FVA value, with 38% of its export value added being foreign compared to 13% for the US (ibid). This is not surprising given the dense nature of intra-EU trade fostered by the Single Market and underpinning EU-wide value chains.

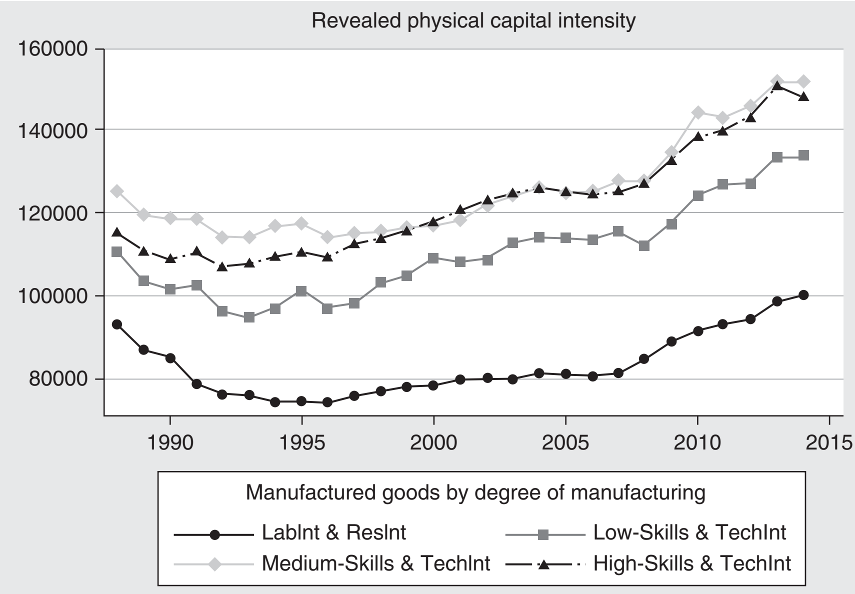

Figure 9.7 Revealed physical capital intensity in the US, 1988–2014.

Source: Authors' elaboration, based on UNCTAD (2018).

Note: UNCTAD distinguished four categories of capital intensity: (i) labour-intensive and resource-intensive; (ii) low-skill and technological-intensive; (iii) medium-skills and technological-intensive; and (iv) high-skills and technological-intensive.

At the same time, *technological change* is transforming the organisation of firms' internal production. As discussed in Chapter 1, firms are expected to become more efficient, agile, flexible and responsive thanks to the adoption of an array of new technologies. We have found an increase in firms' capital intensity as investment in robotisation gathers momentum. Data from UNCTAD shows that across manufacturing sectors with varying degrees of capital intensity, Revealed Physical Capital Intensity rose after the GFC (see Figure 9.7). This suggests that firms have started investing in new technologies by either upgrading existing machinery and equipment or replacing them. Of interest here is the fact that Revealed Physical Capital Intensity investment in medium-skills technological-intensive sectors has been greater than in high-skills sectors. Also, low-skills sectors seem to be those where capital intensity is even smaller, suggesting that new technologies are not replacing low-skill routine occupations. Indeed, we would argue that the penetration of robots at the middle-skill level confirms the rise of a completely different model of manufacturing whereby technology is integrated into production processes at high levels of sophistication (Goos et al., 2009).

In summary, the recent downward trend of FDI to and from advanced economies, and especially from advanced economies to developing ones, could be interpreted as a symptom of a progressive reduction in the length of GVCs. Indeed, the combined effect of a fragile macro-economic scenario and technological change seems to redefine firms' motives and location in terms of production organisation. This suggests in part a renewed attention to invest closer to home, which means either domestically or for European firms within the Single Market. A growing literature has looked at the opportunities and benefits of firms adopting a reshoring strategy, which will be discussed in the next section.

9.5.3 Firms' reshoring strategies

The empirical results in the previous section showed a trend of de-globalisation, which translated as a simultaneously shift of FDIs from developing countries to advanced countries and an increase and consolidation of EU-28 intra-trade. The macro-economic data combined with the revealed capital intensity data can give us a more detailed picture of de-globalisation. As technology is the key point for a reconfiguration of the production system, we can argue that the time is ripe for addressing this reconfiguration of the production system towards advanced countries by adopting the strategy of reshoring.

Reshoring has become something of a buzzword over the last few years. The American media flagged up that some large American MNEs, such as General Electrics and Caterpillar, as well as the largest US retailer Walmart, were bringing manufacturing operations or stocking back home to be able to seal production as being 'Made in USA'. Examples of reshoring have multiplied both in the US and in Europe, and in parallel a large academic and policy debate has expanded (e.g. EY, 2015; PwC, 2014; BCG, 2013). A discussion of the trends in the US and the EU will be discussed in later chapters in this volume.

9.5.4 What is reshoring?

Broadly speaking, in the literature the terms 'reshoring' and 'backshoring' have often been defined as the choice of a MNE to locate back to the home economy a production operation previously offshored: such relocations can include foreign investment or domestic outsourcing (Bailey and De Propris, 2014b). As such, reshoring and backshoring have been used interchangeably. However, we would argue that such a lack of clarity needs to be addressed. In order to conceptually clarify the phenomenon, we decide to consider two dimensions: geography and function. The *geography of firms' production organisation* matters. There is a vast debate on firms' location decision choices in the International Business literature (FDI theories and MNE theories). Yet, most of it has utilised cognitive categories to explain the internationalisation strategies of firms. In the context of reshoring, the 'where to' and 'where from' of movements in firms' production locations are important to the extent that they might be linked to the motives and drivers of such changes. Consider a home economy A and changes in the location choices of firms from and to A as captured by Figure 9.8 below. Starting from a similar point where a function has been previously offshored by a MNE, we suggest distinguishing four forms of reshoring. Although some terms have so far been used interchangeably, we suggest they should be meaningfully differentiated. These are: backshoring, near-shoring, home-shoring and hop-shoring (see Figure 9.9).

A second important aspect to consider is *what functions are actually reshored*. Offshoring strategies were explained by the well-known 'smile curve' (Mudambi, 2008) and tended to involve low-value-added functions; however, firms' current

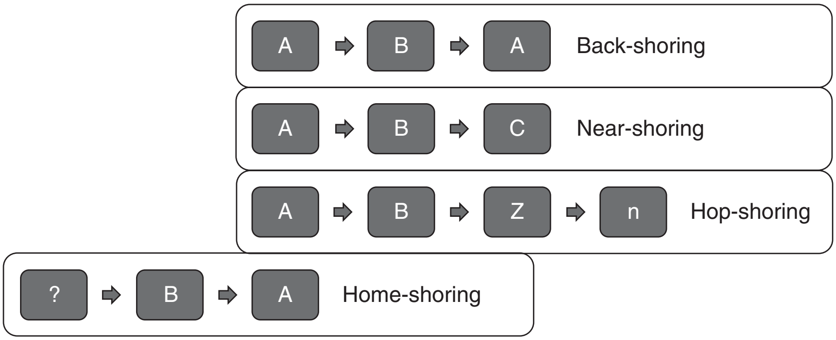

Figure 9.8 Taxonomy of reshoring.
Source: Authors' elaboration, 2018.

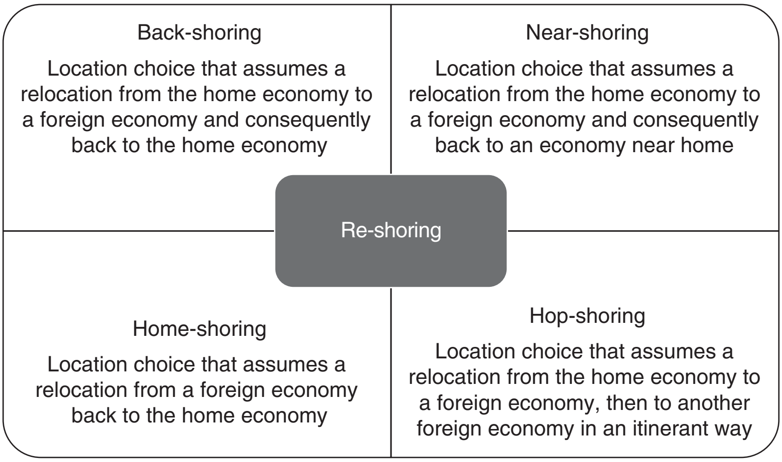

Figure 9.9 Forms of reshoring.
Source: Authors' elaboration, 2018.

location choices are driven by more complex decisions, not least because value chains are no longer linear, but can create multiple-value associated with similar functions in different competitive environments. Therefore, elements of the production function to monitor should be the labour to capital ratio, customisation, production flexibility, value creation, quality, reliability and technology intensity. The last point will be further developed in a later chapter in this volume.

9.5.5 Reshoring and the hidden costs of globalisation

Push and pull factors have been unpacked to understand and explain reshoring as a short-term adjustment to respond to, for instance, the hidden cost of offshoring (Gray et al., 2017; Espana, 2015; Kinkel and Meloca, 2009) or the increasing complexity of value chain governance (Lieb and Lieb, 2016; Lavissière et al., 2016). However, others have suggested that reshoring should be observed as part of firms' longer-term strategy to better face international competition (Moradlou et al., 2017; Młody, 2016a, 2016b; Navarro, 2013).

Some of the *push factors* driving reshoring are related to hidden long-term costs in offshoring strategies (Espana, 2015). Firms faced unexpected operational frictions such as monetary and time-related costs, as well as intangible costs derived from macro-political strategies and country-risk factors (Navarro, 2013). Gray et al. (2017) analysed the reshoring decisions of 19 American SMEs and found that reshoring was chosen to correct a previous decision as more intangible costs had emerged as compared to location advantages at home.

Flexibility, responsiveness and short lead time have been argued to have been key *pull factors*. The concept of 'responsiveness' is linked to the presence of intangible assets that can reduce supply chain frictions. Moradlou et al. (2017) took India as the host country of the UK's offshoring in the automotive, industrial goods, textiles and marine sectors. According to the study, responsiveness was linked to long production lead times and logistics and transportation features such as electricity storage, excessive paperwork and cultural differences in working attitudes. Moradlou et al. (2017) emphasise supply chain constrains rather than a location's limit. It also highlights the importance of cultural distance as a driver for pushing manufacturing production from India back to the UK. Another example is, for instance, the 'Amazon Effect' (Lieb and Lieb, 2016), that is the fast rise of e-commerce. Online shopping requires firms to control regional logistics that integrates with a shopping platform like Amazon. Closeness to consumers, tight control over the supply chain (fewer production tiers) and quicker exchanges (geographically closer suppliers) have been argued to have convinced firms to reshore either internally or externally previously offshored operations. B2C firms in particular have responded to shorter delivery time, small batches of product requests and frictionless supply chains by reshoring their production closer to the end market by leveraging the territorial infrastructure system (Martinez-Mora and Merino, 2014) and a shared coordinated quality management system (Uluskan et al., 2016).

Another crucial pull factor is geographical proximity and access to emerging new technologies. Tate et al. (2014) suggest that firms adopting advanced manufacturing technologies required skilled labour and access to innovation infrastructure, both of which were absent or underdeveloped in developing or emerging economies. This lured manufacturing firms to locate production back in their home economy. Stentoft et al. (2016) also argue that reshoring is not a simple U-turn, but a strategic choice driven by production innovation. They find empirical evidence that automation and innovation are linked to firms seeking a shorter value chain and adopting a reshoring strategy. Indeed, the emergence of a new manufacturing model (see Chapter 1 for more on this) create an urgency for firms to access relevant skills and technological capabilities that are most likely to be located in advanced economies. The empirical evidence of the nexus reshoring and Industry 4.0 is also provided in Chapter 11 of this volume.

As already discussed, FDI has stagnated over the past few years, possibly having peaked in 2007–2008; reshoring trends are in effect the mirror image of how MNEs are restructuring their international production system, which is the fundamental pillar of GVCs. Reshoring cannot be studied as a standalone strategy pursued by a single lead firm, but it has to take into account the territorial features underpinning the firm's choice. In other words, a multidisciplinary approach is required that combines approaches from international business, supply chain management with economic geography.

This means that in order to understand the dynamics of reshoring, we need to move away from the place-neutral approach implicit in firms' internationalisation strategy as conceptualised within the international business subject ('space neutral' is different here from 'space blind'), whereby offshoring location strategies were warranted by any place being relevant as long as they could provide cost savings or access to a specific resource. On the other hand, we would advocate for a different approach to be adopted in order to understand reshoring strategies: they are very much driven by a *place-based rationale*, whereby one place matters – that is, home. In this respect, reshoring can be considered as an expression of a de-globalising trend.

9.6 Conclusion

The aim of this chapter has been to offer insights into an emerging debate on de-globalisation and to provide some supporting evidence. We found that FDI was shrinking and MNEs' value chains were being regionalised within macro-regions. Indeed, trade intensity has increased at the macro-region level, with firms switching to more localised supply chains, even to the extent of shifting production or sourcing from abroad to locations closer to home. The reorganisation of their production process was also driven by the need to leverage the new technologies associated with Industry 4.0.

All this seems to suggest that MNEs are changing their internalisation strategies and are shifting away from polarised GVCs, whereby business functions are geographically dispersed to address a functional polarisation between high and low value-added functions. They are instead preferring to locate production nearer to the final market to accommodate and exploit an emerging business model that sees a continuum along the innovation-production-consumption spectrum. This imposes new priorities and a new urgency to firms' globalisation strategies, and in the aggregate it is reshaping global production around *macro-regional production platforms* where shortened and closer value chains can enable better monitoring, more flexibility, quicker turnaround, better quality control and better responsiveness. Understanding how these are structured and function is the next main challenge for research.

Notes

1 Backward linkages are measured as the share of value added in foreign input used for the production of exporting goods. Forward linkages are measured as the share of value added of a good exported to a trade partner and further processed and exported.

2 For a review of the recent debate on globalisation, see Stiglitz (2006, 2015) and Rodrick (1997, 2010); see Friedman (2005) for the globalisation and inequality growth nexus; and see Baldwin (2016, 2019) for the globalisation and technology nexus.

3 Data is computed from the Annex Table of the World Investment Report, available at: https://unctad.org/en/Pages/DIAE/World%20Investment%20Report/Annex-Tables.aspx.

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10 Reshoring in the US and Europe

Steffen Kinkel, Diletta Pegoraro and Rosemary Coates

10.1 Introduction

The reshoring phenomenon in both the European Union (EU) and the United States (US) is a 'hot' topic as Industry 4.0 is shortening global value chains (GVCs) and new players from emerging markets are aggressively entering the global arena. Securing a strong and competitive industrial base is a focal requisite for advanced economies to remain competitive in today's business environment. This chapter provides evidence of the reshoring phenomenon in the EU and the US. Motives and challenges will be highlighted as well as the role of policy makers in supporting a possible reshoring strategy.

At first glance, we can say that reshoring in the EU is not so relevant, but it is an interesting phenomenon to take into account for revitalizing or for maintaining competitiveness in important industrial zones. In contrast, reshoring in the US is a predominant topic for policy makers, with arguments focused on bringing back jobs to the US.

After an overview section which compares the EU and US contexts, three selected European regions, namely Veneto in Italy, Baden-Württemberg in Germany and the West Midlands in the United Kingdom UK), are presented by way of exploring whether a reshoring strategy is a viable solution for sustainable competitiveness or not. Section 10.7 presents evidence on reshoring in the US, with three criteria highlighted to be considered in adopting a reshoring strategy. Finally, the conclusion presents an overarching list of motives that are driving reshoring decisions in both the EU and the US.

10.2 Reshoring trends from data in the EU and the US

Based on a rich literature review, we have analysed and compared empirical evidence that quantitatively measures reshoring activities in the EU, in selected single European countries and in the US (Kinkel et al., 2017). The following studies have been included:

- The 2012 Eurostat international sourcing survey (Rikama et al., 2013).
- The Uni-CLUB MoRe reshoring dataset (complied by the Italian Universities of Catania, L'Aquila, Udine and Bologna; e.g. Ancarani et al.,

2015; Fratocchi et al., 2014, 2016; Wan et al., 2017) and the subsequent *European Monitor of Reshoring* (*EMR*) (e.g. Ancarani et al., 2017), a collaboration between the EU Eurofound and the Italian CLUB Universities, based on a keyword search in secondary data of the major business-related newspapers, magazines and reports, white papers of major consulting companies and an internet search.

- Studies on European companies' backshoring activities, based on data from the *European Manufacturing Survey* (*EMS*) (e.g. Dachs and Kinkel, 2013; Dachs and Zanker, 2014).
- Longitudinal evidence on offshoring and backshoring activities in the German manufacturing industry (e.g. Kinkel et al., 2017; Kinkel, 2014; Kinkel 2012; Kinkel and Maloca, 2009).
- An online survey of buyers and purchasing managers from companies located in France and Western Europe (Fel and Griette, 2016).
- Results of surveys of UK-based manufacturers (Li et al., 2017; Bailey and De Propris, 2014).
- A comprehensive study on the 'Relocation of Nordic Manufacturing' in the Nordic countries of Denmark, Finland and Sweden (Heikkilä, 2017).
- The 2011 Boston Consulting Group report 'Made in America again' and related follow-up work (Boston Consulting Group, 2011, 2012).

Based on these sources, we have drawn conclusions on evidence of reshoring in the EU and the US, and on the potential and limitations of existing approaches to measure the reshoring phenomenon. The main results and conclusions of this secondary study on similar and differentiating patterns of EU and US companies' reshoring activities can be briefly summarized as follows.

Reshoring seems to be a more common phenomenon in the US than in most European countries. In 2013, more than 20% of the surveyed executives of US companies were actively engaged in reshoring manufacturing, with more than half of executives planning or considering reshoring activities (Boston Consulting Group, 2012). In Europe, the average share of companies active in reshoring at all manufacturing companies, 'adjusted' to a comparable timeframe of two years of activity, is around 4% (Table 10.1). It varies significantly from around 1% in Eastern European countries like Romania and Bulgaria to over 3% in large industrial countries like Germany and the UK, 4% in Nordic countries like Denmark and Finland, around 6% in Belgium and France, and up to 9% in Sweden and Ireland. However, it is very difficult to compare these figures, as they originate from different timeframes (from two to eight years) and, in the case of US surveys, even include companies that are only considering reshoring activities or investing in (new) manufacturing capacities in the US instead of in an offshore country. Thus, comparisons of reshoring levels between different countries need to be interpreted with great care.

Table 10.1 'Adjusted' shares of companies active in reshoring for selected European countries

Country	*Share of companies active in reshoring*	*Timeframe (years covered)*	*'Adjusted' share of companies active in reshoring over a two-year period*
Sweden	27.0%	6	9.0%
Ireland	13.0%	3	8.7%
Belgium	9.5%	3	6.3%
Slovakia	9.0%	3	6.0%
France	14.0%	5	5.6%
Denmark	13.0%	6	4.3%
Finland	13.0%	6	4.3%
DACH	4.0%	2	4.0%
Portugal	6.0%	3	4.0%
The Netherlands	6.0%	3	4.0%
Selected European countries (*EMS* survey)	**4.0%**	**2**	**4.0%**
The UK	13.0%	8	3.3%
Germany	3.0%	2	3.0%
Estonia	3.5%	3	2.3%
Lithuania	2.0%	3	1.3%
Bulgaria	2.0%	3	1.3%
Romania	1.0%	3	0.7%

Note: Source countries for reshoring by US companies are mostly China and other Asian countries, while for European companies, Western and in particular Eastern European countries are most important. However, China and India have also become more important as source countries for European companies' reshoring activities over time.

10.3 The region of Veneto in Italy

10.3.1 Veneto and its manufacturing industry

The Veneto region is located in the north-east of Italy and has for decades been the heartland of Italian manufacturing, hosting a variety of industries that emerged in the post-Second World War period; it has been part of the so-called *Third Italy* (Bagnasco, 1977). Much has been written on the Third Italy, especially in relation to it being characterized by the presence of a large number of industrial districts (Becattini et al., 2014), which flourished in the 1970s and 1980s and some of which are still present today. In Veneto, three main factors favoured the growth of industrial districts: (i) the export-oriented attitude of local firms; (ii) richness in local social capital; and (iii) a long period of domestic economic growth driven by the availability of a large labour pool thanks to internal migration from the southern regions in conjunction with a favourable monetary policy (Tattara and Anastasia, 2003; Bentivogli and Gallo, 2011). In the 1990s, the fast growth of the manufacturing sector and its export success took a new turn, with profound modifications in firms' division of labour (Giunta et al., 2012). Firms in labour-intensive sectors such as textiles and apparel and leather and footwear (TALF) started to delocalize the manufacturing functions to low labour-cost economies (Corò et al., 2013; Crestanello and Tattara, 2011; Dunford, 2006). Since small and medium-sized enterprises (SMEs) in industrial districts tended to be family-owned, their internationalization strategy tended to proceed mostly via offshored outsourcing and joint ventures rather than pure outward foreign direct investment (FDI) (Furlan et al., 2007). However, this offshoring pressure to seek cost-efficiency brought the region to a profound sense of 'crisis',[1] and what was left of traditional manufacturing sectors presented a high degree of heterogeneity both within and across industrial districts (De Marchi et al., 2014). The 2008 Global Financial Crisis added an additional layer of problems mostly due to the long national recession that followed. By the end of 2017, after ten years of profound reorganization, manufacturing in the region still accounted for 97% of micro- and small firms and 55% of the active labour force. The fabricated metal products and TALF sectors are the largest in terms of the number of firms, accounting for 20% and 15% of the total number of firms in the region, respectively.[2]

10.3.2 Evidence on reshoring in the region of Veneto

There is evidence that previously offshored activities are being reshored back to Veneto. A few studies have started to look at the reshoring phenomenon in Italy at the national level (Kinkel et al., 2017), within industrial districts (Bettiol et al., 2017) and as a marketing strategy (Grappi et al., 2015). These studies agree the Veneto region has the highest percentage of firms that have adopted a reshoring strategy.

This section aims to shed further light on the specifics of the reshoring phenomenon in the Veneto region. By combining several sources such as local newspapers, microdata from the Union Chamber of Veneto and analysis of financial reports, we have compiled a list of 311 companies that have adopted reshoring strategies. From this data set we have extracted key information about firms' reshoring strategies. Firstly, we found that of these, one-third are small, one-third are medium-sized and one-third are large companies. Looking closer at sectorial composition, we found that TALF firms have been the most active, especially small-sized firms. On the other hand, in the Machinery and Equipment sector, medium-sized firms have more visibly adopted reshoring strategies. With a 6.4% growth rate in the first quarter of 2018, the industrial variation index for the Machinery & Equipment sector was double the total for the regional economy (3.2%) and the sector also saw investments finally overtake the 2010 level[3] (Callegari and Trevisanato, 2018). Secondly, in relation to the Machinery & Equipment sector, analysing firms' financial statements, we found that reshoring strategies were adopted largely due to internal reorganization or through mergers and acquisition (M&A) activities. Only a few companies in the TALF sectors adopted reshoring strategies to leverage 'Made in Italy' marketing brand value or to reduce lead time. From a careful analysis of financial statements, we found that very few firms reshored via plant closure, and the majority of firms decided to reshore a single product line or to invest in new facilities in Veneto to produce small volumes of high-value products. A third observation is that reshoring seems to co-exist with some offshoring, in that firms have 'brought back' only high-value and niche productions which can command the highest margins.

These observations were subsequently tested with a questionnaire. The survey was administered by the Union Chamber of Veneto in the last quarter of 2017 by adding one specific question on reshoring in the quarterly survey 'VenetoCongiuntura'. Firms were asked if they had in the period 2012–2017 done any of the following activities:

1. Closed a production site abroad and opened a new one in Veneto.
2. Reduced production in a foreign plant and increased production in a domestic plant.
3. Reduced the use of foreign suppliers and increased the use of domestic suppliers.
4. None of the above.

We defined a reshoring strategy as options 1–3 above. We had a sample of 1,200 firms, of which 26 declared as having adopted reshoring strategies. A first result confirms that reshoring in a strict sense (option 1 or 2) is small, with only five firms having selected option 1. It should be noted that these firms have more than 50 employees and operate in the intermediary goods sector. Firms' characteristics endorse the first and second observation, regarding dimension and sector. Of particular note is the finding that 21 firms selected option 3: of these, one is a large company, 16 are of medium size and the rest are micro-firms. In terms of sector composition, 42% of respondents were firms in heavy industries such as mechanics equipment and metal production, while 33% of respondents were in light industries (e.g. textile, leather and eyewear). Finally, of the 26 firms that adopted a reshoring strategy, all of them engaged both in reshoring and offshoring strategies at the same time, which confirms that reshoring was adopted to bring back only high-value, top-end and niche productions.

10.4 The region of Baden-Württemberg in Germany

10.4.1 Baden-Württemberg and its manufacturing industry

Baden-Württemberg is one of the leading economic regions in Germany, with well-known global companies located there, such as Daimler, Bosch and SAP and with many SMEs which are competing successfully in international markets and creating the basis for industrial efficiency and excellence. Two-thirds of all jobs, 80% of trainee positions and more than half of the revenues in Baden-Württemberg are provided by medium-sized companies.

In Baden-Württemberg, the manufacturing industry records a higher share of value added than in any other German state. In 2017, more than 34% of gross value added was attributed to the manufacturing industry. Its macro-economic impact is even larger, as it is strongly inter-connected to industry-related services. In 2017, Baden-Württemberg's manufacturing industry counted 8,200 companies, whose 1.284 million employees generated sales of around €360 billion euros. The federal state's industrial sector has an international focus: the export ratio, measured as foreign sales at total sales, exceeded 55% (2017).

Baden-Württemberg's manufacturing industry features three leading industries: mechanical engineering (25% of employees and 22% of sales in the region, and a 64% export ratio), car manufacturing (18% of employees, 29% of sales and a 72% export ratio), and electrical engineering and electronics (13% of employees, 11% of sales and a 55% export ratio). Together they generate around two-thirds of total manufacturing industry revenues. Alongside these lead industries, the metal-processing industry is also a major element of Baden-Württemberg's industrial profile.

Of all federal states in Germany, Baden-Württemberg invests by far the most in research and development (R&D), with a 4.9% share of R&D expenditures of GDP in 2016. Baden-Württemberg is also the number one region in Germany in terms of patents per capita, with 132 patent applications per 100,000 inhabitants in 2017. Universities, external research institutes (e.g. Max Planck and Fraunhofer) and transfer centres (e.g. Fraunhofer and Steinbeis) between the scientific and business communities are key components of its research infrastructure and successful technology transfer, particularly to SMEs.

10.4.2 Reshoring and Industry 4.0 adoption in Baden-Württemberg

In Germany, only 9% of manufacturing companies offshored parts of their production abroad from 2013 to mid-2015. As will be shown in more detail in Chapter 11, this value is barely higher than the lowest level ever measured since the 1990s. Over the past 12 years, fewer and fewer German companies have reduced their domestic production capacities in favour of foreign locations. In the same timeframe from 2013 to mid-2015, about 3% of German manufacturing companies engaged in the reshoring of foreign production capacities to Germany (Kinkel and Jäger, 2017). Hence, there is currently one reshoring company for every three offshoring companies. While this does not seem to be a major trend, it is nevertheless a relevant phenomenon.

We use data from the same data source, the *EMS* 2015 edition, to illustrate and describe the respective reshoring patterns in Baden-Württemberg. The EMS is a firm-level survey that investigates products, processes, services and organizational innovation in European manufacturing. *EMS* is organized by a consortium coordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI). The survey addressed all manufacturing sectors (NACE Rev. 2 classes 10–33) with at least 20 employees.

The Baden-Württemberg subset of the *EMS* 2015 edition comprises data from a total of 244 randomly selected companies and provides a representative picture of the manufacturing sector in terms of size classes and sector structure.

Of the surveyed companies, 38% have less than 50 employees, 44% have 50–249 employees and 18% have 250 or more employees. Around 24% of the companies belong to the metal processing industry (20% in the parent population), 21% to mechanical engineering (18% in the parent population) and 6% to car manufacturing (4% in the parent population). To further improve the representativeness of the results on offshoring and reshoring behaviour, data was weighted in terms of size classes and sectors.

From 2013 to mid-2015, 2% of manufacturing companies in Baden-Württemberg have performed a reshoring of production capacities from abroad. This is a noticeable but not significantly lower level than the 3% share in Germany as a whole. This lower level might be partly due to the high share of metal processing and mechanical engineering companies in Baden-Württemberg, which overall reported below-average reshoring ratios of 1.9% and 1.4%, respectively. Another reason might be the very high international orientation of the manufacturing industry in Baden-Württemberg, which led to many early, market-driven and sustaining offshoring activities, as local customers could be served directly from foreign locations. This customer-driven approach might have provided a stronger 'glue' and stamina to stay at the foreign location than might have been the case for activities in low-wage locations with respective customers elsewhere.

At the same time, manufacturing companies in Baden-Württemberg show a superior level of adoption of digitization technologies in manufacturing (Industry 4.0). More companies use technologies from all three digital technology fields (digital management systems, wireless human-machine communication and cyber-physical-systems), qualifying them as advanced users (level 3) using the I4.0 readiness index described in Chapter 11. In Baden-Württemberg, 35% of manufacturing companies belong to this advanced group, compared to only 27% of all German manufacturing companies. Conversely, only 16% of the manufacturing companies in Baden-Württemberg belong to the non-users (level 0) of digital technologies in manufacturing, compared to 23% of all German manufacturing companies. Overall, manufacturing companies in Baden-Württemberg on average seem to be more advanced in Industry 4.0 technology use and readiness. This is not surprising, given the innovation strength of the Baden-Württemberg industry and the high importance of Industry 4.0-related industries like car manufacturing or mechanical engineering.

However, this excellent I4.0 readiness index in Baden-Württemberg does not seem to translate into a superior reshoring ratio, as other factors seem to keep most foreign manufacturing activities at their locations. One reason might be that the argument of flexible production of individual products in local value chains might in this case work at least partly in favour of staying at the foreign location, as early on many companies from Baden-Württemberg successfully built up foreign factories close to local customers. Another factor might be that many Baden-Württemberg companies are acting as suppliers or equipment providers for large multi-national lead firms, mainly from the automotive sector.

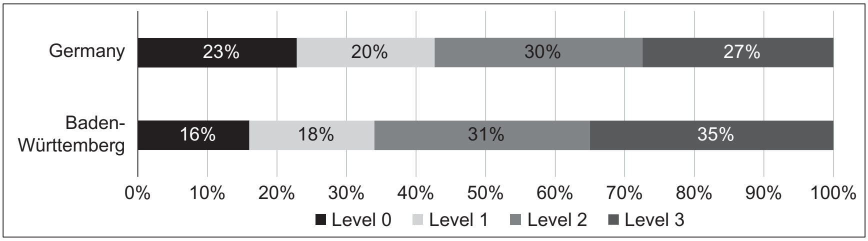

Figure 10.1 Industry 4.0 readiness index in the German and Baden-Württemberg manufacturing industry.

They have built up offshore locations to be close to their lead customers, and these close customer relations seem to provide an effective incentive to keep manufacturing activities of supplier companies at the foreign location, leading to a reduced likelihood of reshoring (Dachs et al., 2017).

10.5 The region of the West Midlands in the UK

10.5.1 The West Midlands and its manufacturing industry

The West Midlands is a UK region with a long tradition in the manufacturing sector. It comprises the Birmingham/Solihull area, the 'Black Country', Coventry, Stoke-on-Trent plus other shires (e.g. Staffordshire, Warwickshire and Worcestershire). The Midlands were the cradle of the First Industrial Revolution with the first large concentration of manufacturing firms in the metal, leather, glass and ceramics industries (MacNeill and Bailey, 2010). Thanks to the availability of labour and embedded know-how in metal materials, a cluster of automotive and aerospace industries flourished. However, since the 1960s, the manufacturing sector has gone through a severe industrial reorganization in the form of functional offshoring and increased foreign ownership (Donnelly et al., 2017), resulting in a significant loss of manufacturing jobs and firms. What was left, however, had to be high technology and positioned at the very top end producing high-value outputs (Bryson et al., 2013).

In recent years, the restructuring of manufacturing in the West Midlands saw a specialization in basic metals and metal products, and transportation and equipment. The specialization in those sectors fostered industries such as advanced manufacturing and engineering, and the aerospace and automotive industries (Eurostat, 2018). According to the West Midlands Industrial Strategy (2018), the automotive sector in the region counts 20 vehicle-manufacturing sites and 35 automotive original equipment manufacturers (OEMs), employs 46,000 people and generates £3.2 billion in gross value added (GVA). The major players in the cluster are Jaguar Land Rover, Aston Martin Lagonda and BMW. However, small and niche innovative companies such as the London Electric Vehicle Company (owned by the Chinese firm Geely) are flourishing. The region also hosts 10% of the British aerospace industry, with companies such as Rolls-Royce, UTC Aerospace System and Moog leading the cluster. The rail sector is linked to its historical metals production and remains important for the region, together with low carbon industries that are attracting innovative companies addressing the broader national sustainable agenda. The high-value medical technology and life science cluster is also crucial for the West Midlands economy through the application of AI, digital technologies and data analytics trials.

10.5.2 Reshoring in the West Midlands

In the last four years, the UK manufacturing sector steadily increased the number of employees up to 145,000 units in March 2018. However, the productivity index is reversing, suggesting that companies are hiring more people but not investing in new technologies. Some analysis confirms this, as one-third of the employment recorded in March 2018 was in low-tech activity (e.g. cutlery, radiators and screws). However, the transportation sector revealed signs of an opposite trend, employing highly skilled labour. In the automotive sector, there was an employment increase of 42,000 plus another 13,000 in other mobility-related sectors (e.g. aerospace, ship and train) up to 2018. Some commentators believe that this positive trend in manufacturing employment could be driven by a reshoring trend (*Financial Times*, 2018).[4]

Reshoring in the UK, especially in the West Midlands, has not been investigated in detail as yet. There have been no surveys on reshoring in West Midlands and official data do not capture the motives for bringing back manufacturing activity. However, De Propris and Bailey (2014) highlight the opportunities and challenges of reshoring in the automotive sector. Currently, the automotive sector is undergoing a disruptive technological transformation with the introduction of electric and driverless vehicles (Bailey, 2018). To unlock these challenges, Jaguar Land Rover for example invested £3.7 million in a R&D project called CORTEX in partnership with the University of Birmingham to further develop autonomous and connected cars (Jaguar Land Rover, 2018). The firm is also investing £500 million at its Whitley site in Coventry (Mullen, 2018), and in 2019 announced – despite job losses – investment in electric drivetrain assembly at its i54 engine plant and battery assembly at a new plant at Hams Hall, near Birmingham, as well as electric vehicle manufacturing at Castle Bromwich. While Jaguar Land Rover has expanded its manufacturing sites in China and Slovakia, it is keen to stress that it is also investing in British manufacturing sites for those activities related to high-value manufacturing, demonstrating its goal to pursue a truly international strategy.

In the West Midlands, another case of home-shoring was Mondelez-owned Cadbury. Mondelez has invested £75 million over the last few years in upgrading its manufacturing plant in Bourneville, Birmingham and 'brought home' the production of some Dairy Milk bars from Poland and Dairy Milk Tiffin and Dairy Milk Oreo from Germany (*Daily Telegraph*, 2017). The limited production run of Dairy Milk Tiffin in the summer of 2016 became permanent in the summer of 2017, leveraging a consumer trend for nostalgic products (Mintel, 2018).

In the broader Midlands region (including the East Midlands), the textile and fashion industries are also historically significant. Lead firms in these sectors highlighted speed and flexibility as key drivers for offering 'fast-fashion' products, as well as the value of premium British-based brands able to leverage the authenticity of a 'Made in the UK' label. In Leicester, the fashion and textile industries in 2017 employed 9,500 people in 1,480 businesses. Further exogenous factors such as currency fluctuation and/or Brexit could further trigger a reshoring of production in the area. Business opportunities suggest that businesses in this sector should invest in technical textiles, composite and intermediate textile goods in order to satisfy valuable niche markets (Focus, 2017). The city of Leicester is the second-largest hub of fashion and textiles in the UK; some concerns have been raised about some instances of 'modern slavery' in some of its firms (*Just-Style*, 2018) and this could be a problem as sourcing is increasingly scrutinized by ethically conscious consumers; major retailers such as Asos and New Look expect the highest standards in order to decide to locate in the UK and in particular to reshore production to Leicester.

10.6 Challenges in adopting a reshoring strategy in the EU

Adopting a reshoring strategy is an intense and costly effort, whether a company decides to bring home production home either by opening a plant or by home-sourcing. The first implies heavy investment, while the second requires establishing trust with domestic suppliers, and a vibrant local supply chain (Bailey and De Propris, 2014). In particular, a common challenge faced by firms in adopting a reshoring strategy is the availability of skills and a competent workforce. In particular, high-skilled manufacturing roles are predominant in driving a reshoring strategy both in Veneto (Italy) and in the West Midlands (UK). For example, it took an Italian firm four years to upgrade its workforce internally with competent engineers and to reorganize its supply chain for more flexible production.[5] In the West Midlands case, Jaguar Land Rover is investing £100 million a year into its JLR Academy, which has already upskilled 7,000 master-educated employees since 2010.[6] In contrast to these two European regions, the Baden-Württemberg region does not suffer from a lack of technological skills of its workforce, due to its superior commitment to I4.0. However, specialists with corresponding digital skills (e.g. software development, data analysis and IT design) have become very scarce in the meantime. This shortage of skilled workers is a central challenge, especially for SMEs. Thus, as highlighted previously, the adoption of I4.0 technology in Baden-Württemberg companies is rarely translated into a reshoring strategy, but it is fundamental for the prosperity of the region as an important value-adding node embedded in GVCs. This last point is key for German firms, as their competitiveness is also driven by their participation in GVCs and therefore highly dependent on the lead firm's strategy. Many Baden-Württemberg companies are suppliers or equipment providers for large multi-national lead firms, mainly in the automotive sector, as shown above. They have to adopt advanced manufacturing and I4.0 technologies to be able to participate in these highly competitive value chains. They also need to build up offshore locations to be close to their lead customers' foreign factories. As noted, these close customer relations of supplier companies seem to provide an effective incentive to keep their manufacturing activities at the foreign location and to reduce the likelihood of reshoring (Dachs et al., 2017).

10.7 Reshoring in the US

10.7.1 Offshoring and the momentum for bringing manufacturing back to the US

Offshoring to China and other low-cost countries has caused the loss of about five million US manufacturing jobs over 20 years, has helped contribute to worker wage erosion and has had a negative effect on workers and the economy across America. Local communities have lost approximately 27% of their manufacturing workforce since 2000. About 63% of the job losses are due to the offshoring of jobs.[7] During the 2012 US presidential election, both Barack Obama (Democrat) and Mitt Romney (Republican) were blaming the sluggish economy on the outsourcing of US manufacturing to China. This rhetoric gave rise to serious executive conversations about the possibility of bringing manufacturing back to the US, if economically feasible, and for patriotic reasons, termed 'Economic Patriotism' by the Reshoring Institute.[8] Beginning in 2012, reshoring and manufacturing expansion (those companies that decide to expand domestically instead of moving overseas) have enjoyed steady growth. This growth can be attributed to several factors:

- intellectual property theft concerns in China;
- rising Chinese wages for high-labour-content manufacturing;
- low energy costs in the US;
- introduction of automation such as 3D printing, robotics and advanced machine tools;
- reduction of latency in deliveries to US consumers;
- lower corporate tax rates (2017 reduction to 21%);
- lower tax rates for repatriation of overseas funds (2017 reduction to 15%);
- relaxation of environmental regulations;
- consumer preference for goods made in the US.

During this same period, individual states offered significant local tax and other incentives such as training credits and infrastructure development to attract and keep manufacturers in their state. In some cases, state and local governments offered free property, data services and cash incentives to attract manufacturers. This is because manufacturing has an economic magnifier effect on local economies, promising new jobs and a greater tax base. For every $1.00 spent in manufacturing, another $1.89 is added to the US economy. That is the highest multiplier effect of any economic sector. In addition, for every one worker in manufacturing, there are another four employees hired elsewhere (National Association of Manufacturers).[9]

In 2017, the average manufacturing worker in the US earned $84,832 annually, including pay and benefits. The average worker in all non-farm industries earned $66,847. Looking specifically at wages, the average manufacturing worker earned more than $27 per hour, according to the latest figures, not including benefits.[10] These numbers put manufacturing workers squarely in the American middle class.

Taking a more informed and analytical approach to global manufacturing strategies and the cost of overseas production, American executives started to evaluate the possibility of bringing manufacturing home. In addition, American politicians began campaigning heavily on a 'jobs platform'. The momentum for this kind of informed analysis has grown over the past ten years, especially since the election of a Republican government – the party most favoured by American manufacturers for its policies on reducing taxes and eliminating environmental regulations.

For the first time in decades, more manufacturing jobs are returning to the US than are going offshore. Reshoring, plus foreign direct investment (FDI) surged in 2017. Manufacturing job announcements reached 171,000, up 50% from 2016 and a remarkable 2,800% from 2010. This brings the total number of manufacturing jobs brought to the US from offshore to over 576,000 since the manufacturing employment low of 2010. The 171,000 reshoring and FDI job announcements equal 90% of the 189,000 total manufacturing jobs added in 2017.[11]

The resurgence of US manufacturing and other jobs has been on a steady incline since the Great Recession of 2008–2010. Job growth rates climbed under the Obama Administration and the Trump Administration. However, enthusiasm for manufacturing is typically greater under Republican administrations. Coupled with tax rate restructuring, manufacturing is experiencing a positive rebirth and outlook in America.

10.7.2 Selected case studies

GE Appliances

GE Appliances provides an interesting reshoring example. In the 1990s, the CEO of GE, Jack Welsh, shut down much of GE's domestic appliance manufacturing, moving operations mostly to China. Even Asian appliance manufacturers and OEMs such as Samsung established primary manufacturing in China. This was done to leverage very low labour costs, low operating costs and the resulting increased profit margins. For GE, the manufacture of traditional water heaters was well suited to low-cost Chinese manufacturing to supply the US market and the burgeoning Chinese consumer market. But when Jeff Immelt became CEO in 2002, he challenged GE engineers to develop new products and technologies. One of the newest products was a heat-on-demand water heater called Geo-spring. The primary market for the Geo-spring was the US, due to its expensive price tag.

GE manufacturing engineers worked with design engineers to automate a very efficient production line that minimized labour and was cost-efficient. Lean manufacturing was added to Six Sigma programmes to keep quality high and costs low. GE then reopened manufacturing in Louisville, Kentucky at GE Appliance Park. In addition, GE worked with local labour unions for wage concessions and eventually rehired 4,000 workers for several new production lines. The GE Appliance division was later sold to Haier Appliances, a Chinese company, for $5.4 billion in 2016. Haier now operates the Appliance Park facility.[12]

iRT Wheels: technology for elite cyclists

The use of advanced technology in manufacturing can reduce labour requirements and cost, improve quality and reduce supply chain latency. One example is iRT Wheels in Pasadena, California. CEO Ray Asante is an engineer by training and a former competitive cyclist. He began manufacturing and selling wheel hubs for elite cyclists in the early 2000s. Initially iRT Wheels designed the hubs in California, then ordered wheel hub prototypes from Taiwan at a cost of $7,000–$10,000, plus $5,000–$10,000 in duty, taxes and shipping fees to be delivered within 60–90 days. If the prototype was not correct, the process would have to be repeated, making new moulds, with more costs and time delay. Prototypes were sent back to California for adjustments, then sent back to Taiwan for manufacture.

In 2013, iRT Wheels purchased a 3D printer and started printing the prototypes and hubs in California. This process reduced per-unit costs, improved quality and allowed for the delivery of new hubs to elite cyclists within 48 hours. Rush orders can be delivered in 24 hours. In the competitive cycling world, this is a remarkable competitive advantage. This move to 3D printing saved the iRT Wheels $100,000 over two years and significantly improved customer service.

Use of Foreign Trade Zones: Lam Research, Silicon Valley

The introduction of technology is important to the overall cost factors in making reshoring decisions, but it is not the only factor. Process and strategy can also be important decision factors. For example, the use of a Foreign Trade Zone allows for in-zone manufacturing, assembly, manipulation or storage. No customs duty is changed on the goods in a Zone until they are removed from the Zone and formally imported into the US. If the goods are subsequently exported form the Zone, they are not imported or taxed in the US.

Lam Research, a $14 billion manufacturer of semiconductor equipment in Silicon Valley, uses Foreign Trade Zones extensively as part of its product and global logistics strategy. Parts from worldwide suppliers are brought into multiple Silicon Valley Foreign Trade Zones, to be incorporated into finished products, combined with domestic parts and products, or warehoused as spares. This carefully controlled physical environment is considered 'outside US Customs Territory' and goods kept there are considered foreign and restricted.

Once an order from a Lam Research customer is received, the products ordered are assembled inside the designated Zone and are then either shipped to a foreign customer or imported to be sold domestically. Each customer order is highly configured and unique.

Use of the Lam Research FTZs keeps manufacturing jobs in the US, delays or avoids the payment of Customs duties, and creates hundreds of new jobs managing the Foreign Trade Zone warehouses and operations.

Buy American

According to a study by *Consumer Reports* magazine, eight out of ten American consumers say they would prefer to buy an American-made product than an imported one. In several studies conducted by Walmart, the world's largest retailer, and other consumer groups, over 60% of shoppers say they are willing to pay 10–15% more for items made in the US.[13] These statistics are used to drive reshoring decisions based on economic factors. If a manufacturer can produce products that are no more than 15% more expensive than similar foreign-made products, Americans will choose the US product.

In determining the economics of competitive manufacturing in the US, the Reshoring Institute uses the 15% margin target to guide total cost of ownership (TCO) modelling. The TCO can help guide the executive decision to bring manufacturing home.

The decision to manufacture in America is therefore guided by three decision criteria:

1. *Economic analysis* including the total cost of ownership modelling and cost reduction through automation and process efficiencies.
2. *Government support* through state and local incentives and federal corporate tax cuts, and reduction of regulations regarding manufacturing.
3. *Consumer Buying Preference* for products made and labelled 'Made in the USA'.

10.8 Conclusion

The magnitude of reshoring depends on the sectoral and value chain composition of the firms in a territory, as a reshoring strategy is more likely to be implemented by companies pursuing an individual customer-oriented strategy in the domestic market. The main motivations for reshoring are different between the territories of the EU and the US, and to some degree also between different regions in the EU. Table 10.2 below shows the push and pull factors

Table 10.2 Push and pull factors for reshoring in the EU and the US

	EU	*US*
Push Factors	Quality issues Loss of flexibility Delivery time Transportation costs Reduction of labour cost gaps Total costs of sourcing	Loss of know-how, intellectual property theft Reduction of labour cost gaps Total costs of sourcing Transportation costs Costs of control Delivery time Quality issues
Pull Factors	'Made in' preference Proximity to lead firms Investment in technology for advanced manufacturing Incentives for investment in I4.0 technologies	Low energy costs (in the US) Investment in automation technology Vicinity of production to R&D Relaxation of environmental regulations Lower corporate tax rates and tax rates for repatriation of overseas funds 'Made in' preference Feeling of patriotism

that trigger a reshoring strategy, differentiated by the EU and the US as home regions. Some factors are shared between the two territories, while others are related only to a single territory.

The most important push factors for reshoring activities of European manufacturing companies are quality issues, loss of flexibility and delivery time, transportation costs, the reduction of labour cost gaps and the total costs of sourcing. The most important pull factors are the 'Made in' reputation effect, the proximity to lead firms in the home country, and investments and incentives to implement advanced manufacturing and I4.0 technologies to make production at the home base more competitive. Innovation-related factors like the loss of know-how or the vicinity of production to R&D are less important for reshoring of European companies in the regions studied here,[14] as are some other manufacturing costs such as energy costs.

In the US, different cost factors, like rising labour costs at the offshore country, the total costs of sourcing, transportation costs or the costs of control, represent some of the most important push factors for reshoring. Also, intellectual property theft concerns in the offshore country and the consequent loss of know-how are seen as a very important boost for reshoring activities. The most important pull factors for reshoring to the US are: low energy costs in the US; the introduction of automation technologies such as additive manufacturing, robotics or advanced machine tools; the vicinity of production to R&D; lower corporate tax rates; and lower tax rates for the repatriation of overseas funds.

Overall, the narrowing cost levels between emerging and developed countries seem to be more important for US companies' than for European companies' reshoring activities. Conversely, quality issues and losses of flexibility and delivery time seem to be relatively more important for European companies. Also, the exploitation of the 'Made in' buying preference effect is a reshoring driver that seems to be more important for European than for US manufacturers.

In addition, policy plays a different role for supporting reshoring activities in the EU and the US. Reshoring in the US is more directly supported by policy makers, e.g. by lower corporate tax rates, state and local incentives or by direct pressure on US companies to produce and buy in their home country. The US federal government also enforces the Buy American Act of 1933, requiring US government agencies to always purchase products made in the US unless they are not made or available in the US (US Code 41 U.S.C. §§ 8301–8305).

The US 232 and 301 import penalty tariffs have negative effects on the manufacturing performance of US companies, as they damage export strategies and make foreign imports of raw materials, parts and products simply more expensive. In the EU, reshoring activities are more indirectly supported by the focus of European industrial policies on more inclusive growth. Promising measures to potentially support reshoring activities indirectly without having to subsidise them directly could include, among others:

- supporting regional clusters and local value chains;
- supporting local demand for innovative and more sustainable solutions (e.g. public procurement and 'Made in' local value chains);
- supporting the development and adoption of smart production systems (e.g. I4.0, agile and individualized manufacturing, additive manufacturing);
- supporting the development of smart, data-driven services and business models for B2B;
- supporting the education, qualification and competence development of skilled personnel, and limiting bottlenecks in digital key competences.

Despite these differences in motivations and supporting policies, manufacturing reshoring is considered to be an important strategy to increase the value of the territory, both in the EU and in the US.

Notes

1 Between 2007 and 2012, Italy faced both the Global Financial Crisis and the European debt crisis.

2 Data on firms dimensions, employee numbers and sectors compositions have been provided by the Union of Chamber of Commerce of Veneto, December 2017.

3 Data from the Eurostat series 'Annual detailed enterprise statistic for industry' (NACE Rev, 2, B-E), 'Code sbs_na_ind_r2'.

4 However, a combination of a fall in sales in China, the decline in diesel sales and Brexit uncertainty led to around 1400 job losses at Jaguar Land Rover in 2018, with another 4000+ job losses announced by the firm in early 2019.

5 2016 anonymous firm's Financial Statement.
6 2018 JLR Financial Statement.
7 US Department of Labor, Bureau of Labor Statistics, www.bls.gov/.
8 www.reshoringinstitute.org.
9 www.nam.org.
10 Bureau of Economic Analysis and Bureau of Labor Statistics, 2017 www.bls.gov.
11 Reshoring Initiative,www.reshorenow.org.
12 Reshoring Institute Case Studies, www.ReshoringInstitute.org.
13 See www.reshoringinstitute.org.
14 For a counter view on production and R&D in Spanish manufacturing 'home sourcing' see Bailey et al. (2018).

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11 Industry 4.0 and reshoring

Steffen Kinkel

11.1 Introduction

The rise of global value chains (GVCs) has transformed the global manufacturing landscape dramatically in recent decades (Timmer et al., 2016; Brennan et al., 2015). Globally fragmented production processes often result in products consisting of components from a variety of countries, which can be best described as 'made in the world' (WTO, 2011).

However, highly fragmented supply chains come at a price. Disadvantages include higher coordination efforts, a longer time-to-market, quality issues, a loss of flexibility and a loss of the ability to react quickly to changes in market demand (e.g. Fratocchi et al., 2014, 2016; PricewaterhouseCoopers, 2014; Kinkel, 2012; BCG, 2011; Kinkel and Maloca, 2009). Moreover, the rise of GVCs and the offshoring of production activities have been blamed for job losses in manufacturing sectors of the US and European countries.

As a result, the so-called reshoring or backshoring of once-offshored manufacturing capacities back to the home country has recently received broad attention in the academic literature (e.g. De Backer et al., 2016; Di Mauro et al., 2018; Kinkel, 2014; Stentoft et al., 2016; Wiesmann et al., 2017), and even more by policy makers and in public debates. The debate on re-industrialization (Pisano and Shih, 2009, 2012) in the US and Europe is to some extent based on expectations that reshoring activities of manufacturing companies might help to restore industrial competitiveness in high-wage countries. It is fuelled by the assumption that cost advantages of important low-wage countries, in particular China, may be gradually eroded by higher wage increases in the next five to ten years (BCG, 2011).

This chapter investigates the relationship between investments in new digital production technologies, which are currently discussed under headings such as 'Industry 4.0' (I4.0) or 'Industrial Internet of Things (IIoT)', and reshoring or backshoring decisions of manufacturing companies.

It is assumed that the use of I4.0 technologies may affect GVCs in two ways: first, because increased productivity provided by I4.0 production technologies may neutralize the factor cost advantages of offshoring locations and make labour arbitrage less appealing; and, second, because increased flexibility provided by I4.0 technologies may provide an incentive for firms to locate production close to their European customers and regain some of the responsiveness lost by having finely sliced their global supply chains.

The empirical test is based on a large dataset of almost 1,300 German manufacturing companies from the *European Manufacturing Survey* (*EMS*). This dataset has the advantage of including variables on both reshoring and investments in modern production technologies, and a number of additional control variables.

11.2 Definitions and some theory on reshoring and I4.0

11.2.1 Reshoring/backshoring

Reshoring or backshoring is the decision to relocate manufacturing activities back to the home country of the parent company (Kinkel and Maloca, 2009; Arlbjørn and Mikkelsen, 2014; Fratocchi et al., 2014; Foerstl et al., 2016). Reshoring or backshoring can origin from and be relocated to wholly owned production sites of the company (captive mode) as well as from foreign suppliers or to home-based suppliers (outsourced mode), thus covering different ownership modes of manufacturing in the host and home countries. In this context, Gray et al. (2013) distinguish four different reshoring options (see Figure 11.1): (a) in-house reshoring, when a company is relocating manufacturing activities being performed in wholly owned offshore facilities back to wholly owned facilities in the home country; (b) reshoring for outsourcing, when a company is relocating manufacturing activities being performed in wholly owned offshore facilities back to home-based suppliers; (c) reshoring for insourcing, when a company is relocating manufacturing activities being performed by offshore suppliers back to wholly owned facilities in the home country; and (d) outsourced reshoring, when a company is relocating

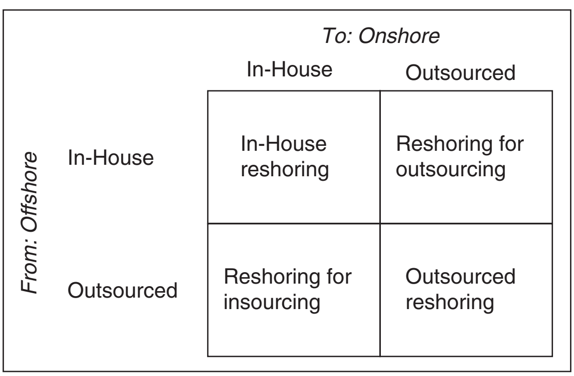

Figure 11.1 Reshoring options.
Source: Gray et al. (2013).

manufacturing activities being performed by offshore suppliers back to home-based suppliers. The authors characterize all these different options basically as location decisions.

There is no explicit theory of reshoring or backshoring. The literature explains reshoring in the framework of existing theories of the multi-national firm, as a reverse or subsequent decision of a previous offshoring decision (Bals, et al., 2013; Ellram et al., 2013; Gray et al., 2013; Tate, 2014; Foerstl et al., 2016). To put it simply, reshoring takes place when the trade-offs between cost advantages, market and knowledge seeking, transaction costs and maintaining control are no longer advantageous for the firm.

Through the lens of *internalization theory* (Buckley and Casson, 1976; Casson, 2013; Rugman, 2010) and Dunning's 'eclectic paradigm' (Dunning, 1980, 1988), reshoring is the result of changes in the ownership, location and/or internalization advantages from international production, or a consequence of a wrong assessment of these advantages (Ellram et al., 2013; Fratocchi et al., 2016). The international expansion of multi-national firms was fuelled by labour arbitrage, a substantial lowering of import barriers for intermediate goods, lower cost of cargo transport and the rapid development of ICTs which supported trans-border communication and coordination (Dicken, 2014). Factors that contributed to a wrong assessment of location, internalization or ownership advantages include rising labour costs in foreign locations and narrowing wage differentials, transport costs and long lead-times in transport, currency fluctuations, the cost for obsolete materials ordered according to a long-term and incorrect forecast, unforeseen coordination costs such as additional travelling expenses, or a loss of intellectual property to foreign competitors or suppliers (Handfield, 1994; Kinkel and Maloca, 2009; Holweg at al., 2011; Nassimbeni, 2006). Case studies have shown that some managers have offshored manufacturing activities based on simple comparisons of easily measurable costs, in particular labour costs (Kinkel and Maloca, 2009).

The *resource-based view* (RBV) of the firm (Wernerfelt, 1984; Prahalad and Hamel, 1990) can also be applied to explain reshoring strategies. Firms can develop organizational processes and routines that cannot be acquired over markets, enabling them to use resources and develop capabilities more efficiently and effectively (Barney, 1991; Teece et al., 1997, 2002). Reshoring decisions may thus result from the limited abilities of companies to sufficiently develop and maintain such critical capabilities in foreign locations, or to exploit the host country's resources in order to create competitive advantage for the multi-national company as a whole (Canham and Hamilton, 2013). Here, advanced production technologies also come into play. Some organizations are able to adopt manufacturing processes to develop unique and barely imitable competences at specific locations and to exploit these resources in a specific and more effective way (Broedner et al., 2009; Grant, 1991).

Transaction cost theory (TCT) can also help us understand reshoring. High and growing transaction and coordination costs can be strong arguments for reconcentrating manufacturing activities via reshoring. TCT points to various reasons for a wrong assessment of the 'hidden' costs of offshoring. *Bounded rationality* and possible contingencies in transactions across companies and countries may lead to inaccuracy of the projected cost and performance of manufacturing offshoring decisions (Pisano, 1990; Pisano and Shih, 2009; Lewin et al., 2009; Cabral et al., 2013), higher than expected costs, poorer than expected quality and higher than expected efforts for the management of trans-border activities (Fredriksson and Jonsson, 2009; Tate et al., 2009). Biases in decision making such as the 'bandwagon effect' (Abrahamson and Rosenkopf, 1993), aiming at imitating competitor behaviour and 'following the herd', can also be explained by bounded rationality (Barthélemy, 2001).

The *level of uncertainty* is also influencing companies' offshoring and reshoring decisions. Foerstl et al. (2016) differentiate between environmental uncertainty, supply chain complexity and task uncertainty as possible drivers for reshoring decisions. *Environmental uncertainty* encompasses the perceived degree of volatility and unpredictability of a foreign market, including unforeseen cost increases, quality and flexibility issues, raw material shortages and currency fluctuations (Ellram et al., 2013; Gray et al., 2013; Tate, 2014). *Supply chain complexity* includes vertical complexity, horizontal complexity, geographical dispersion and the length of the supply chain (Choi and Hong, 2002). It can lead to excessive coordination and monitoring efforts, rising transportation cost or high amounts of working capital in safety stock (Lewin et al., 2009; Tate et al., 2011; Ritter and Sternfels, 2004). *Task uncertainty* is another factor influencing offshoring and reshoring decisions. Here, to some extent, the uncertain potential of technological innovations in manufacturing processes, e.g. by an intensified use of I4.0, come also into play. A greater adoption of I4.0 might enable more flexible, autonomous and less labour-intensive production modes, giving advantages to reshoring decisions over low-wage manufacturing activities (Handley and Benton Jr., 2013; Lasi et al., 2014). *Asset specificity* is also closely linked to the implementation of new product or production technologies, e.g. I4.0 technologies. It involves specific durable investments such as technology or knowledge and skills that are required to realize efficient processes and transactions. A high degree of asset specificity appears to be most critical for the integration of manufacturing activities and their control under unified governance (Williamson, 1985), in particular in cases of high product or process complexity (McIvor, 2009). The higher and more specific investments in advanced production technology are, the higher the possibility to integrate the specific manufacturing operations at one focal plant, favouring reshoring rather than additional offshoring activities.

11.2.2 Industry 4.0

Many observers today agree that we are witnessing a technological revolution in manufacturing (Brynjolfsson and McAfee, 2014; Ford, 2015; OECD, 2016, 2017). This revolution is based on a variety of digital production technologies (e.g. sensors and actors, networked production, advanced robotics and 3D printing), new materials and IT-enabled management processes (e.g. enterprise resource planning and production control, data analytics and artificial intelligence). In the manufacturing context, this group of technologies is often labelled as the Fourth Industrial Revolution – after mechanization, electrification and automation (Figure 11.2) – or I4.0 (Kagermann et al., 2013; Spath et al., 2013; Bauernhansl, 2014). The German term 'Industry 4.0' is widely used in the European context and sums up a group of production technologies where components and machines communicate and coordinate their operations in factories and (global) value chains (Brennan et al., 2015; Bauernhansl, 2014; Kagermann et al., 2013; Spath et al., 2013; OECD, 2017; UNCTAD, 2017). Observers expect that I4.0 will allow a highly flexible and at the same time highly efficient production which makes it possible to produce individualized products under the economic conditions of a mass producer (Lichtblau et al., 2015).

A main component of I4.0 are cyber-physical systems (CPSs), which comprise 'smart machines, warehousing systems and production facilities that have been developed digitally and feature end-to-end ICT-based integration, from inbound logistics to production, marketing, outbound logistics and service' (Kagermann et al., 2013, p. 14). This is done by embedding technology that can take on tasks like sensing or automation into physical objects and connecting them via the Internet. In other words, CPSs integrate all stages of the physical production process over the Internet in order to create a seamless exchange of information between these two worlds.

11.2.3 Research question

This chapter tests the assumption that firms' adoption of I4.0 technologies – via productivity and flexibility effects – affects location decisions of manufacturing activities. If I4.0 really leads to higher productivity, a higher degree of customization and more flexibility to manufacturing firms, this may offset the labour cost advantages firms enjoy in offshoring locations. As a consequence, Western Europe may become again a more attractive location for manufacturing because firms benefit from geographical proximity to their customers – 'in the market and for the market' (Brennan et al., 2015) – without suffering from higher production costs. Proximity to the customer is increasingly competing with the long-dominant GVCs, incorporating a variety of operations from different low-wage countries, resulting in high complexity and increasing flexibility disadvantages, especially in the case of short-term and individual customer requests (Kinkel et al., 2016).

Against this background, the *research question* is posed as follows:

> *Is there a positive relationship between the propensity for reshoring/backshoring and the use of I4.0 technologies in manufacturing companies, once we correct for other firm characteristics?*

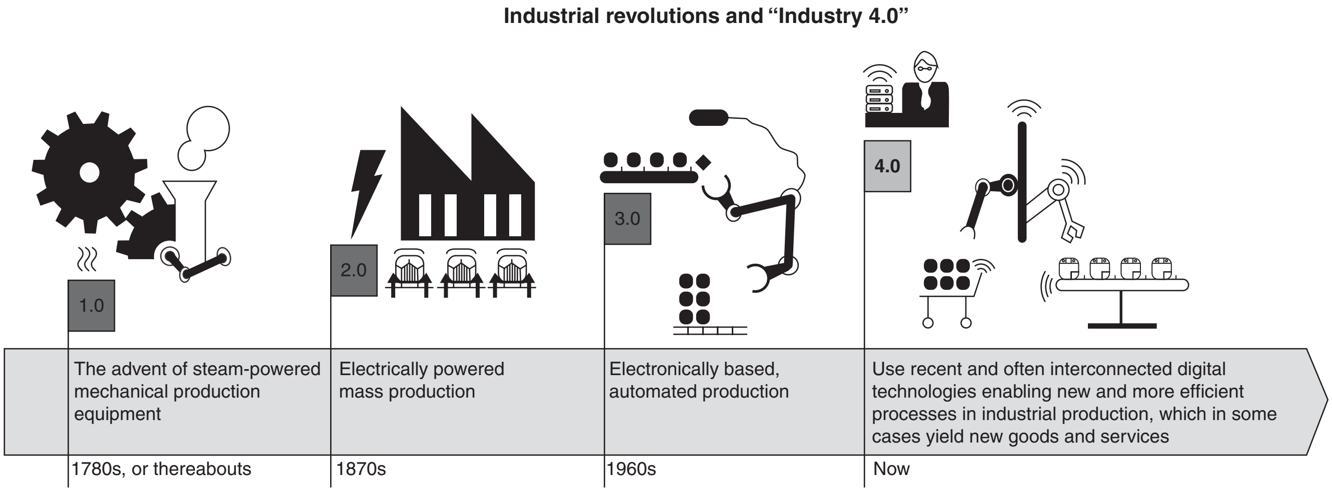

Figure 11.2 Industrial revolutions of the past and I4.0.

Source: OECD (2017).

11.3 Data

The relationship between reshoring/backshoring activities and the use of I4.0 technologies is tested with German data from the 2015 edition of the *EMS*. The *EMS* is a firm-level survey that investigates product, process, service and organizational innovation in European manufacturing. It is organized by a consortium coordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI).

The *EMS* includes detailed information on the degree of utilization of a number of production technologies, on innovation input such as research and development (R&D) expenditure, innovation output such as the introduction of new products to the market, the qualification structure of the employees, and a number of control variables such as firm size, exports, the position of the firm in the value chain and the characteristics of the main product and of the production process. This makes it possible to study the effects of reshoring/backshoring and investment in production technologies in detail.

The German subset of the *EMS* 2015 comprises data from a total of 1,282 randomly selected companies (Kinkel and Maloca, 2009). It provides a representative picture of the manufacturing sector in Germany in terms of size classes, sector structure and regional distribution. The survey addressed all manufacturing sectors in Germany (NACE Rev. 2 classes 10–33 with at least 20 employees). In order to ensure the representativeness of the results and comparability with earlier analyses, the descriptive data on offshoring and backshoring behaviour were weighted in terms of size classes, sectors and regional structure analogously to the population of all manufacturing enterprises with 20 or more employees.

The *EMS* measures reshoring/backshoring asking firms whether they had relocated production activities from their own affiliates or from suppliers back to the home country during the past two years. As a consequence, backshoring is not just divestment of assets abroad; it also includes activities which have been contracted out to third parties. In other words, backshoring firms do not necessarily possess affiliates and production activities abroad.

I4.0 technologies are counted with an array of questions on the use of eight different digitization technologies that can be understood as enabling technologies for digital networked production according to the I4.0 model.

11.4 Descriptive results on reshoring

As the descriptive results of the survey round of 2015 show, the backshoring of production capacities has risen slightly compared to the 2012 survey results. From 2013 to mid-2015, about 3% of German manufacturing companies have shored parts of their foreign production capacities back to Germany (Kinkel and Jäger, 2017). This does not necessarily mean that a foreign site had to be closed, as partial capacities may also have been transferred back. At the same time, production offshoring activities abroad continued to stay at a low level.

Only 9% of German manufacturing companies offshored parts of their production abroad from 2013 to mid-2015. This value is only barely higher than the 8% at the last survey in 2012, which represented the lowest level measured since the start of the survey in the mid-1990s (Figure 11.3). Thereby the declining trend of the past 12 years has not yet reversed. Fewer and fewer German companies reduce domestic production capacities in favour of foreign locations.

Hence, there is currently one backshoring company for every three offshoring companies. A share of about 3 per cent of firms choosing to backshore suggests that backshoring is not a big trend. However, it is a relevant phenomenon. When extrapolated to the entire German manufacturing sector, absolute numbers account actually for around 500–550 German companies performing backshoring activities per year. Further time-series analysis of panel data shows that every fourth to sixth offshoring activity is countered by a backshoring activity within two to five years (Kinkel, 2014). Approximately 20% of German companies' backshoring decisions can be characterized as mid- to long-term reactions to changing local environments, whereas 80% can still be characterized as short- to mid-term corrections of prior location misjudgements (Kinkel, 2014; Kinkel and Maloca, 2009).

The main source countries of German companies' backshoring activities were the Western European EU 15 countries (32%), followed by other (than China) Asian countries (23%), North America (16%), China (13%), and the Middle and Eastern European EU 13 countries (10%). In the previous surveys of 2012, 2009 and 2006, the EU 13/12/10 have been much more important for German companies' backshoring activities, accounting for around 50% of the backshoring cases in each round.

The most important reasons for the backshoring activities of German manufacturing companies are the lack of flexibility (56%) at the offshored location or in the resulting supply chain and a low quality (52%) of the goods produced. Both reasons are relevant for more than half of all backshoring decisions and remained virtually unchanged since the last survey. The reduced flexibility and delivery capability may be due to problems and distances in their own supply chain between the sites, as well as limited access to local supplier networks abroad. Quality issues stem from underestimated efforts to ensure the desired product and process quality in countries with a different mentality and culture, as well as internal quality assurance efforts. On the other hand, innovation-relevant factors such as the risk of loss of know-how at the foreign location (6%), the proximity to domestic R&D (5%) or the availability or fluctuation of skilled workers at the foreign site (0%) play a minor or no role for the reshoring decisions of German manufacturing companies.

11.5 Descriptive results on the use of digitization technologies/Industry 4.0-enabling technologies

The *EMS* includes questions on the use of eight different digitization technologies that can be understood as enabling technologies for I4.0. These were assigned to the following three technology fields:

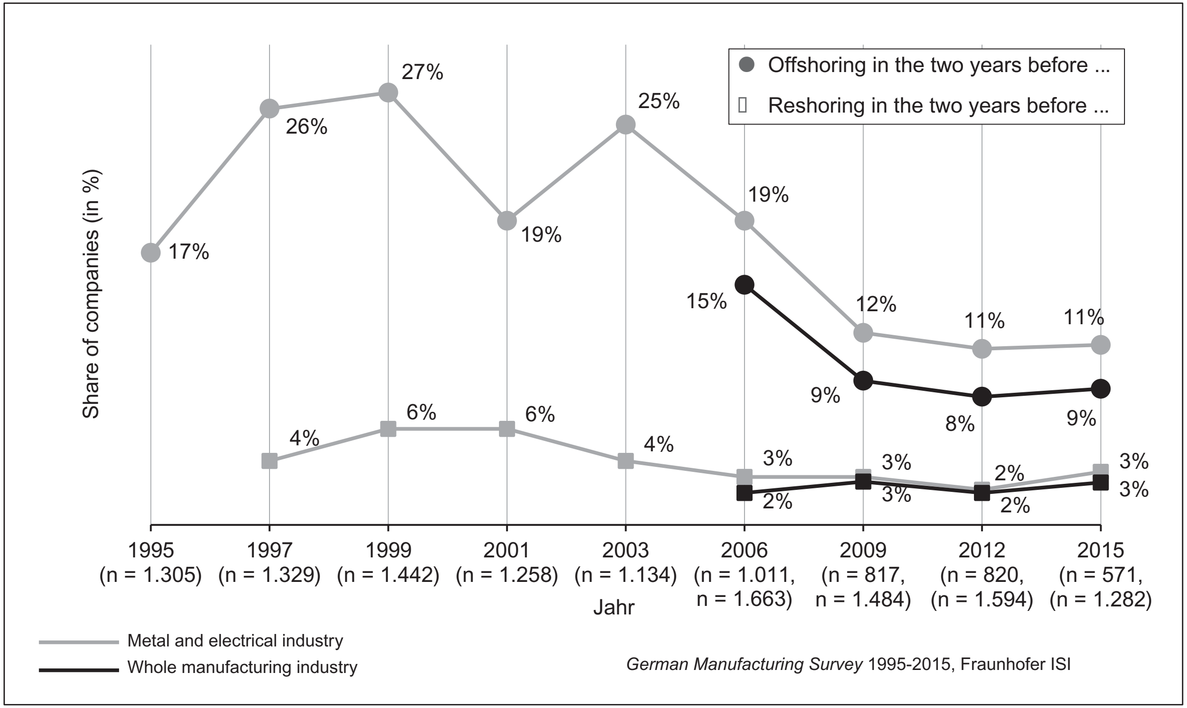

Figure 11.3 German manufacturing companies' offshoring and backshoring activities over time.

- *Digital management systems* comprise two basic technologies for the management of IT-related processes of production and product development:
  - software systems for production planning and control (enterprise resource planning (ERP));
  - product lifecycle management (PLM) systems.
- *Wireless human-machine communication* encompasses two workplace-supporting IT implementations:
  - digital visualization in the workplace;
  - mobile/wireless devices for the programming and operation of systems.
- *CPSs* encompass production-integrated enabler technologies for I4.0:
  - digital exchange of disposition data with suppliers or customers (supply chain management (SCM));
  - techniques for automation and control of internal logistics;
  - a real-time manufacturing execution system (MES).

The share of German manufacturing companies already using these digitization technologies in their manufacturing processes is displayed in Figure 11.4.

As expected, enterprise resource planning (ERP) systems are the most widespread; two out of three manufacturing companies are using this technology. They are already an established standard in production systems. PLM systems, the second technology from the field of digital management systems, are used by only 11% of the companies and thus much less frequently. The systematic and customer-specific retention and management of product data therefore still seems to place high demands on the management and production processes of companies. Diffusion is quite low, with 6% of the companies planning to introduce such systems in the next three years. In the case of production and planning systems, this is due to the already high level of penetration; in the case of PLM, however, this is rather sobering and raises questions about the usage barriers.

One-third of the companies use technologies for the digital visualization of the most important information at the workplace in their own production processes. The second technology from the field of wireless human-machine communication, mobile devices for programming and operating systems and machines, is being used by almost one-fifth of the companies. Both technologies in this field also show a comparatively high dynamic of 8–10% of the companies planning to introduce these technologies in the next three years.

A good quarter to almost a third of the surveyed manufacturing companies use the three digitization technologies in the field of CPS-related operations, Digital Data Exchange with customers and/or suppliers to enable SCM, technologies for the Automated Logistics and Real-time Production Control System. This means that the technologies in this field are used on a comparably broad basis. However, the dynamics of the launches planned for the next three years vary. In the case of Digital Data Exchange with customers and/or suppliers, only a further 5% of companies plan to introduce this technology, which indicates a certain degree of maturity of this technology to support

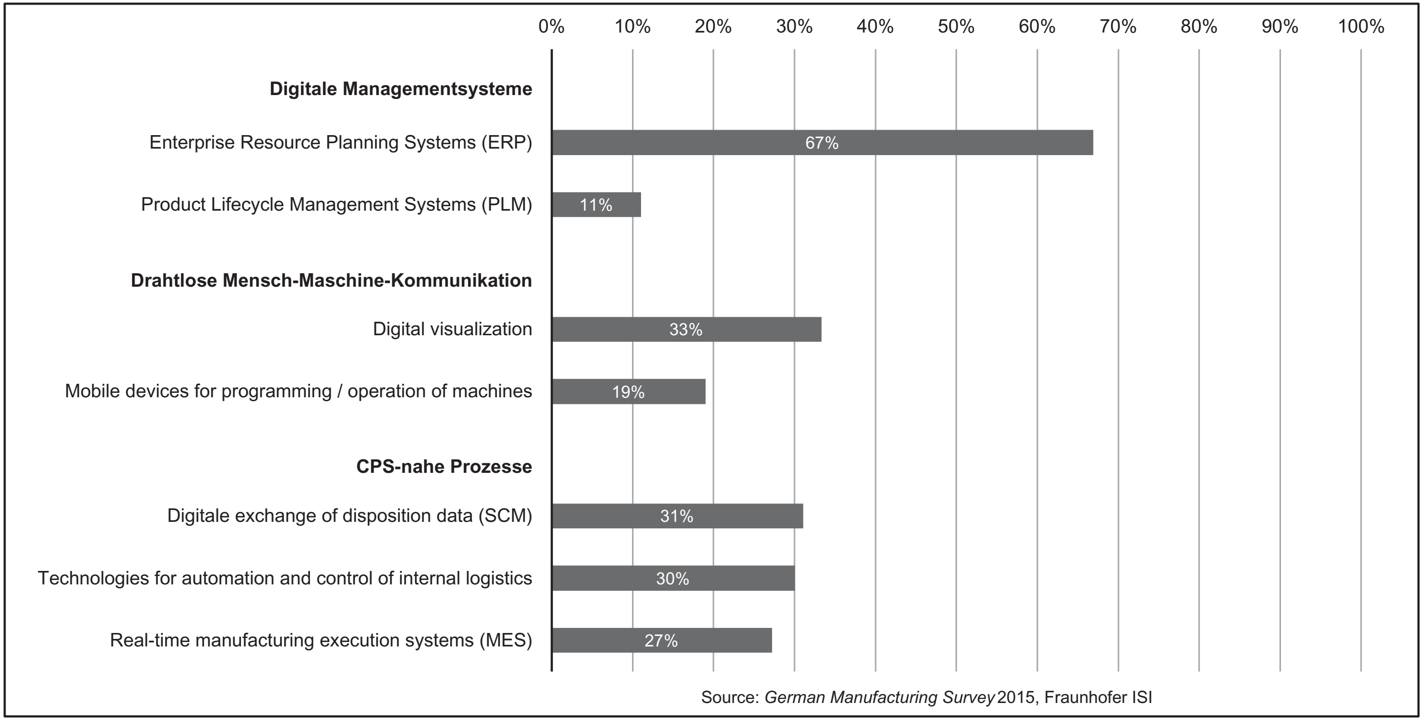

Figure 11.4 Use of I4.0-enabling technologies in the German manufacturing industry
Source: Kinkel and Jäger (2017).

SCM. With the Automated Logistics and the Real-time Production Control System, the dynamics are much higher, with 10% of the companies planning to introduce these technologies in the next three years.

11.6 The relationship between the backshoring of production activities and the use of digitization technologies in manufacturing

A recent study by Kinkel and Jäger (2017) investigates the relationship between reshoring/backshoring of production activities and the use of digitization technologies in manufacturing (I4.0). In order to measure this relationship, the information on the usage of single I4.0-enabling technologies was used to create an I4.0 readiness index. This index can take four values:

Level 0 (non-user) if the company has not yet introduced any technology from the three technology fields.
Level 1 (beginner) if the company has introduced at least one technology from one of the three different technology fields.
Level 2 (active user) if the company has introduced technologies from at least two of the three different technology fields.
Level 3 (advanced user) if the company has introduced at least one technology from all three different technology fields.

If this I4.0 readiness index is applied to the data of the 2015 survey, the following picture emerges (Figure 11.5): 23% of German manufacturing enterprises do not yet use any of the selected digitization technologies and are therefore still at the very beginning of the path towards I4.0 (level 0 – non-users); 20% of the enterprises use at least one technology in one of the technology fields (level 1 – beginners); 30% use at least one technology in two of the technology fields (level 2 – active users); and 27% of the enterprises

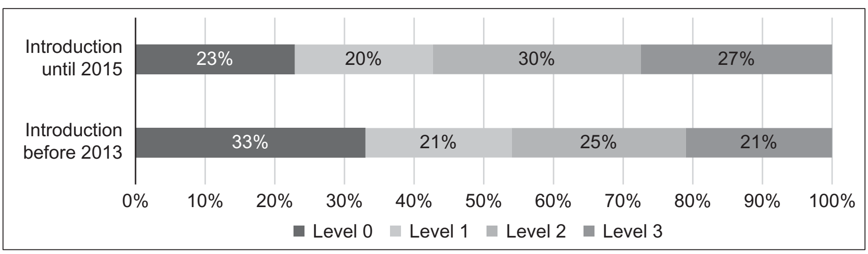

Figure 11.5 Distribution of I4.0 readiness index values.

Source: Kinkel and Jäger (2017), translated from German language.

use at least one technology from each of the three technology fields (level 3 – advanced users). The 'advanced' companies are already positioned in such a way that they have already gained experience with today's enabling technologies in all three of the technology fields relevant for I4.0. However, this group is remarkably small, with just over a quarter of German industrial companies in this category.

As the reshoring activities are surveyed for the years from 2013 to 2014 and the impact of previous technology usage was to be examined, only the introduction of digitization technologies before 2013 is considered in the following regression model (Figure 11.5). The descriptive analysis shows that 33% of the German manufacturing companies did not use any of the selected digitization technologies before 2013 (level 0). The group which introduced at least one technology in one of the technology fields before 2013 (level 1) includes 21% of the companies. About 25% of the companies belong to level 2 and a relatively small group of 21% to level 3.

Based on this I4.0 readiness index before 2013, we ran a logistic regression model to explain the likelihood of a German manufacturing company to have been active in backshoring manufacturing operations during 2013–2014. The model is significant and shows satisfactory model quality (Table 11.1).

Table 11.1 Logit model for the backshoring propensity of German manufacturing companies

Cox & Snell: 0.055	*Nagelkerkes: 0.230*	*Regression coefficient B*	*Sig.*
Step 1	Ln#employees	.072	.673
	sec24_metal & metal components	–.093	.938
	sec26_Data processing equipment, electronic and optical products	.691	.561
	sec27_electrical equipment	.439	.724
	sec28_machinery &equipment	–1.023	.415
	medium batch size	.329	.593
	large batch size	-.152	.850
	medium complex products	-.383	.532
	complex products	–.248	.730
	supplier company	–1.485	.004
	maincompetition factor: price/cost	.574	.310
	Lnimport quota of inputs-	.143	.468
	Lnexport quota of inputs1	.101	.004
	Ln share ofunskilled workers	.137	.439
	I40-enabling-use-til-2013_level11	.884	.095
	I40-enabling-use-til-2013_level21	.932	.076
	I40-enabling-use-til-2013_level32	.618	.016
	Constant	–8.946	.000

Source: Kinkel and Jäger (2017).

The results show that supplier companies show a significant lower backshoring propensity than manufacturers of end products (original equipment manufacturers (OEMs)). This can be explained by close ties with customer companies at the foreign location, which often have to be supplied flexibly from a short distance, so that proximity to the customer is advantageous. In addition, the backshoring propensity increases with the export rate of the companies. For German companies that rely on an export model, the quality and flexibility of their production are decisive factors, which are also the most important motives for backshoring activities. In addition, the label 'Made in Germany' is often helpful for these companies in order to successfully sell their premium products abroad.

The results also display a *significant positive correlation between the use of digitization technologies in manufacturing and the backshoring propensity of German manufacturing companies*.

Advanced users (level 3), which introduced at least one technology from each of the three technology fields before 2013, have significantly more often shifted foreign production activities back to the German location than non-users (level 0) of digitization technologies. According to the estimation model, advanced users of digitization technologies display on average a ten times higher backshoring propensity (approx. 5%) than non-users of digitalization technologies (approx. 0.5%). Also, beginners (level 1) and active users (level 2) are showing a higher backshoring propensity than non-users (level 0), albeit at a lower 10% level of significance.

Two arguments can be used to explain this correlation:

- First, the use of digitization technologies can lead to increased automation and productivity at the German production site, so that the labour cost ratio becomes lower, labour arbitrage in low-wage countries is less appealing and economies of scale at the remaining factory sites in developed countries become more important.
- Second, the use of digitization technologies can be used to increase the flexibility and ability for customized production in small batches with very low marginal cost, which allows the efficient and timely serving of individual customer requirements, and offers incentives to companies to bring back or hold production close to their European customers (leading to local value chains).

According to both arguments, the intensive use of digitalization technologies can significantly contribute to more attractive production conditions with increased added value at the German location.

11.7 Conclusions

Overall, the pressure for greater flexibility and responsiveness is likely to grow in the future, thus suggesting increasing consideration of backshoring options. Our results suggest that companies are continuing to internationalize their activities, but with greater sensitivity to critical factors than in the past. The advantages of cost-based offshoring activities to low-wage countries seem to diminish more and more as time passes, while market-related expansion investments in emerging markets, in order to get closer to the local customers and serve their needs in time, might gain further significance.

However, it is not easy to restore product and process competences outsourced some years ago and restore their 'industrial commons' (Pisano and Shih, 2009). In many cases it might be easier to build up capabilities for the next generation of products or technology, e.g. in the new and vibrant area of I4.0 technologies, as relearning of once-outsourced competences can be a difficult process and only results in catching up rather than becoming a market leader (Kinkel, 2014).

In light of the new potential of I4.0 and smart digitized manufacturing technologies, companies are increasing their focus on utilizing the strengths and potentials of their home base in high-wage countries in Europe. Therefore, we might envisage the beginning of a new strategic imperative of *relocalized manufacturing* (Brennan et al., 2015; Kinkel, 2014) in important markets, with a strong focus on regional concentration and specialization of the necessary engineering and manufacturing competences. Complete solution providing capabilities will be installed in all relevant markets, bidding farewell to further slicing value chains over locations with least-cost advantages, which has led to very complex, multi-stage global supply chains that often comprise many different players and locations. Such global chains are also vulnerable to damage in one of their links, endangering the reliability and responsiveness of the whole chain, which is a crucial condition for the success of companies in today's global economy.

Other factors supporting localized manufacturing (Brennan et al., 2015; Foresight, 2013) are as follows:

- Providing customized products and services, making it necessary to develop and produce customized solutions in smart and agile (responsive) modes close to local clients (Forfas, 2013; Foresight, 2013; McKinsey Global Institute, 2012).
- Rising labour costs in emerging countries as a result of their economic catching-up processes, rendering their comparative cost advantages more and more marginal compared to developed countries with a highly skilled workforce and lower wage volatility (Forfas, 2013; Foresight, 2013).
- Reduced weight of labour costs in total production costs, due to continuing automation and efficiency improvements in many manufacturing firms. For example, currently in the German manufacture industry, direct labour costs account for only around 10% or less of production output value. These progresses are paced by innovations in information and communication technologies and manufacturing technologies towards smart and digital factories, and I4.0 technologies play a vital role here.

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12 Technological readiness in Europe

EU policy perspectives on Industry 4.0[1]

Mafini Dosso

12.1 Introduction

The new technological and innovative developments promised by the next industrial revolution come with their corollaries of optimistic and pessimistic scenarios for our societies. Today, public policy is still tackling digital transition issues; meanwhile, it is already acting on and anticipating the challenges and opportunities, and the risks and uncertainties, of the emerging Industry 4.0 (I4.0) paradigm. This chapter acknowledges these trends and provides an insider view on the background of the policy support given by the European Union (EU)[2] to the transition towards the new industrial age.

While the third production revolution brought its waves of innovations through a wider penetration of information and communications technology (ICT) and automation, I4.0 is expected to extend, accelerate, connect and scale up these disruptions and transformations, and to trigger a wider integration across domains and discoveries. It will enable this through the multiplication of interactions across the physical, digital and biological spheres (Schwab, 2016)[3] allowed by the convergence of new and emerging technologies and materials and the related technology-enhanced processes and systems, including 3D printing, the Internet of Things (IoT), big data and cloud computing, artificial intelligence (AI), advanced robotics, smart factories, precision farming and agriculture, fintech, neurotechnology, micro-engineering, predictive medicine, synthetic biology and predictive gene-based healthcare. The transformational and disruptive nature of the ongoing and upcoming technology-enabled or -pushed changes are already altering our learning, education, consumption, distribution, productive, financial, legal and governance systems (see e.g. Smit et al., 2016; Ulmann 2017; Craglia et al., 2018). They modify our established conceptions of privacy and ownership, work organisation, industries and competitive markets, and prompt the adoption of new business and governance models, as well as new collaborative and sharing practices.

From a policy perspective, these developments call for, amongst other things, adequate public anticipations and responses in terms of societal awareness raising and acceptance, learning and training, technology adoption and diffusion, support to production systems upgrading and value creation, data security, and standards and regulatory frameworks across various industries and socio-economic domains. While they also entail a variety of opportunities to rethink public policy and its (participatory) processes, the (un)expected and unprecedented transformations of I4.0 are indeed already requiring more agile and anticipatory governance. At the EU level, I4.0 can be considered as a central component of innovation, industry and digital policies, even if in practice the responsibilities are distributed across EU-level institutions and the Member States with their governments and administrative bodies, institutions and agencies.

Setting up the foundations of the Europe 2020 Strategy[4] for smart, sustainable and inclusive growth, the EU has designed dedicated flagship initiatives – 'Innovation Union', 'An industrial policy for the globalisation era' and 'A digital agenda for Europe' flagships (European Commission, 2010a) – to strengthen the framework conditions and environment in the EU economy. Through these early broad and thematic policy initiatives, the Commission has put the development and adoption of emerging and digital technologies at the centre of its growth and modernisation agendas (European Commission, 2010b, 2010c, 2010d). Already, around a decade ago, the game-changing potential of key enabling technologies was underlined for the development of entirely new industries and as a response to societal challenges in areas relating, for instance, to energy, environment and resource scarcity (European Commission, 2009, 2010d). This study departs from these early initial policy steps and examines the main evolutions in the background and policy rationales for the support for the transition towards I.4.0 in Europe. The qualitative analysis mainly relies upon official European Commission communications[5] and EU reports as well as thematic national and regional strategies. It brings together an updated and structured picture of some of the rationales and directions of I4.0-enabling policies in the EU.

The remainder of the chapter is organised as follows. Section 12.2 describes the EU policy background and underlines the main related rationales for the support for the transition towards I4.0. Section 12.3 presents and compares the recently formulated I4.0 policy strategies at the national levels. Then selected regional strategies are discussed, focusing on the policy objectives and formulation as underlined in their innovation strategies for smart specialisation.

12.2 Industry 4.0: EU policy background and main rationales

12.2.1 EU policy background: an overview

The initial efforts to develop key enabling technologies (KETs)[6] and advanced manufacturing as engines of the EU's growth trajectory led to the identification of priority action lines for the EU's industrial policy and investments into new technologies. Building upon the 2010 communication (European Commission, 2010d), the policy proposals for *A Stronger European Industry for Growth and Economic Recovery* (European Commission, 2012) put forward six fast-growing initial priority areas, including: markets for advanced manufacturing technologies for clean production; markets for key enabling technologies (micro- and nano-electronics, advanced materials, industrial biotechnology, photonics, nanotechnology and advanced manufacturing systems); bio-based product markets; sustainable industrial policy, construction and raw materials; clean vehicles and vessels; and smart grids (European Commission, 2012). These priority markets and technological areas constitute essential components of the industrial policy responses to the economic crisis and formed the basis for the development and modernisation of 'the industrial infrastructure needed for what has been identified as a new "Industrial Revolution"[7]' (ibid, p. 7). High in the concerns was thus the need to speed up investment in breakthrough technologies in fast-growing areas and to capitalize upon and exploit their transformative potential in order to reverse the manufacturing decline. Based on the works of dedicated tasks forces, further policy priorities along the initial areas were proposed for a *European Industrial Renaissance* (European Commission, 2014). These included, for instance, the implementation of knowledge and innovation communities, public–private partnerships (PPPs), the identification of projects of European interests, thematic initiatives, inter-regional cooperative efforts to realise joint investment projects, and dedicated funding schemes for enabling and industrial technologies and breakthrough advances, for instance, under the EU Horizon 2020 programme[8] (see also European Commission, 2015a for an early assessment of the European strategy for KETs).

In addition to the more supply-oriented initiatives, the Commission has gradually integrated a lead user market approach also enshrined in the strategy for the Digital Single Market (DSM)[9] (European Commission, 2015b, 2016a; Burh and Stehnken, 2018; Smit et al., 2016). Lead market strategies intend to stimulate the demand for adoption and diffusion of novel innovation designs (Beise and Cleff, 2004). The DSM communications recognise the multiple opportunities of digital technologies and the major challenges for *Digitising European Industry* deriving, for instance, from the large disparities across firms and European territories, the need for digitally skilled workers, an improved supply of digital consumer products and Web services, a critical mass of investments in digital innovation and infrastructure, and the importance of designing targeted policy actions in the field of data regulation and standardisation. On this latter point, five priority areas for standardisation have been selected focusing on 5G, cloud computing, the IoT, (big) data technologies and cyber-security (European Commission, 2016b) as the technology building blocks of the DSM.

Beyond the technological issues, the digital transition has wider social and economic implications and is changing the labour market conditions and the nature of work and skill mixes (e.g. digital and complementary entrepreneurial, engineering and power or soft skills – see Smit et al., 2016; Ulmann 2017). Acknowledging these structural changes, *A New Skills Agenda for Europe* underlined the main proposals to address the digital skills gaps in Europe and to encourage the development of digital skills strategies across Member States

(European Commission, 2016c). The many important challenges and opportunities of digital and key enabling technologies are again underlined in the successive and more recent communications on industry and innovation policies (see, for instance, European Commission, 2017a, 2018). These different proposals have paved the way and have contributed to the recent establishment of dedicated platforms (e.g. the European Platform of National Initiatives on Digitisation and digital industrial platforms). In parallel, key funding sources have been identified, for instance, from the European Fund for Strategic Investments,[10] Horizon 2020 as well as the European Structural and Investments Funds (ibid).[11]

The priority areas underlined in the previous communications also constituted important building blocks of the EU Regional and Cohesion Policy for the period 2014–2020. Within this policy framework, regions were required to design their Smart Specialisation Strategies[12] as an 'ex-ante conditionality' to access the European Regional Development Fund.[13] Smart specialisation strategies (S3) are socio-economic transformation agendas that aim at identifying priority research and innovation (R&I) investment domains in order to build up sustainable competitive advantages in the regional economies. As part of their smart specialisation strategies, regions were encouraged to collaborate through the Smart Specialisation Platform for Industrial Modernisation (S3P-Industry). Launched in 2016, S3P-Industry intended to facilitate the establishment of inter-regional partnerships and joint investment projects in areas relating to digital technologies and I4.0, and to reinforce the links among industrial value chains across Europe (Hegyi and Rakhmatullin, 2017).

The aim of this section has been to underline some of the fundamental orientations of the EU policy for industrial innovation and technological development. Taken together, EU official communications provide important conceptual pillars of the EU policy background for the digital era and for the transition towards I4.0. Besides, they make it possible to highlight common and consensual motivations across the different thematic policy intervention areas. The next section examines in further detail these key communications in order to put forward the broad policy rationales advanced to support the European digitalisation and industrial transition towards I4.0.

12.2.2 Broad policy rationales

Strengthening the manufacturing sector in the EU through the adoption of new technologies constitutes one of the fundamental rationales for I4.0-enabling policies. The role of the manufacturing sector in terms of direct and indirect jobs, export and private research, and innovation efforts in the EU economy has been acknowledged in successive communications from the European Commission. These latter policy documents have also made explicit the need to reverse manufacturing decline and to bring back to 20% the weight of industry in the EU's gross domestic product (GDP) by 2020. The 20% target has also been underlined in the political guidelines for the current European Commission as a necessity in order to strengthen the EU's industrial base (Juncker, 2014). This objective raises major scale and policy challenges beyond the sole realm of innovation and industrial policies. One structural issue, as underlined by Berger (2014), resides in the current structure and de-industrialisation trends in EU, which do not leave much room for manoeuvre, also considering the decline of manufacturing (and the parallel rising value-added share of services) observed in other advanced and even emerging economies (Berger, 2014; European Parliamentary Research Service, 2015). Moreover, achieving the target requires coordination across a broader scope of policy areas such as energy, raw materials, capital, trade, education and training, business services, advanced technologies, standards, intellectual property (IP) and the single market in order to improve the overall framework conditions for industrial development (European Commission, 2012, 2014a; Veugelers, 2013; European Parliamentary Research Service, 2015). This means that continued enhanced coordination across the Commission's Directorates and Member States may well contribute to improving the general industrial environment in Europe with an industrial policy that can enhance the impact of targeted investment in new technologies for the advancement of manufacturing systems and the modernisation of industry.

In addition to its importance for economic growth, the manufacturing sector, and its role in research and development (R&D) and innovation, can provide both resources and potential solutions to tackle and address the societal challenges faced by the EU, such as health, climate change, food security and the development of a safe and secure society. A main rationale is that the adoption of I4.0 technologies can enable completely new kinds of better-quality and customised products and services across all economic sectors, while also allowing production to be more efficient from economic, social and environmental perspectives. Also, new and smart technologies are perceived as enablers for environmentally and socially sustainable manufacturing and for the set-up of economically and ecologically sustainable value chains across the EU. From the perspective of more integrated value chains in the EU, the single market is thus seen as pivotal, even vital, for a successful adoption and diffusion of new technological developments, and thus as a driver of the EU's industrial competitiveness (see, for instance, the industrial policy communication: European Commission, 2017a).[14] Yet, much is still to be done to advance or reinforce the lead in the global competition in green and clean technologies and smart manufacturing. Some of the answers will certainly lie in the EU strategic value chains that will be selected and supported and, eventually, in our ability to integrate and connect innovation systems and clusters across Europe, as well as to attenuate the (effects of) disparities that exist between regions, industries and firms (see European Commission, 2016a; Innobarometer,[15] Business Innovation Observatories, Digital Economy and Society Index (DESI)[16] in European Commission, 2017c; Digital Innovation Monitor[17] 2018 in European Commission, 2018a; and Vezzani et al., 2018 for comparisons of innovation performances in the EU).

By encouraging inter-regional collaborations and bottom-up initiatives for industrial modernisation, the Cohesion Policy's smart specialisation framework might actually hold some keys to unlock I4.0-enabled and sustainable cross-regional value chains in the EU. This also means that partnerships should be based on evidence-based matchings and assessments of related-industrial capabilities, skills and potential for critical mass, and that capacities for adequate monitoring and benchmarking need to be built up or reinforced. For the great diversity of European micro-firms and SMEs, important constraints on their transition towards I4.0 come from their awareness and understanding of the new model, of the benefits of absorption, the technology uncertainty, the costs of investment, economic impact assessments, issues around security, and the availability of I4.0 competences and skilled workers. At the same time, pressures to reinvent the ways in which firms deliver value to customers and markets and inter-connect through current and future value chains are no less important (Smit et al., 2016; Ulmann 2017). Nevertheless, hopes that I4.0 can allow the EU's industry to become attractive again for production and manufacturing activities are rising. In other words, advanced manufacturing technologies can be instrumental to aid reshoring in the EU (see Chapter 11 in this volume).

I4.0-oriented skills are required for the modernisation and digitalisation of EU industry. The skills shortage and mismatches in fields such as ICTs, green technologies, advanced industrial processes, fast-growing industries, science, technology, engineering and mathematics (STEM) subjects, research, creativity and entrepreneurship, and the importance of anticipating digital and I4.0-enabling skills needs are widely recognised in the EU policy background. In the ICT field in particular, it is estimated that Europe could have a major shortfall of ICT professionals in the short to medium term. Modernising the EU industrial skills bases and filling (digital) vacancies pose many imperatives for our traditional education systems, vocational education and training, as well as our lifelong learning frameworks and mechanisms. Especially in the transition towards I4.0, such investments should rely upon the development of dedicated tools to monitor and anticipate needs and mismatches at the EU, country, regional, local and industrial levels. Recent multi-stakeholder initiatives such as the 'Blueprint for Sectoral Cooperation on Skills'[18] and the 'Digital Skills and Jobs Coalition' are expected to contribute to address digital and sectoral skills mismatches in the EU (European Commission, 2016c). In addition to skills shortages, growing tensions are emerging within the exiting workforce due to the ongoing and pressing changes at both the organisational and factory-floor levels, leading, for instance, to complex imbalances between control, liability, flexibility, autonomy and empowerment, and to the greater human–machine interactions enabled by the adoption and diffusion of smarter technologies (see e.g. Craglia et al., 2018; Cirillo et al., 2018; UN DESA/DPAD, 2017). The scale and depth of these imbalances may differ greatly across industries and types of occupations (see e.g. Brynjolfsson et al., 2018; Frey and Osborne, 2017). These changes have come with the phenomena of polarisation, jobs creation, destruction and transformation, and a series of labour market shocks, which call for enhanced skills planning capabilities and forward-looking governance mechanisms to anticipate, for instance, potential worker displacements due to the introduction of new production technologies and new labour rights in the digital economy. I4.0 technologies and processes also bring to the fore many legal and accountability concerns and would certainly require the setting-up of completely new forms of working and social contracts, which could account better for the socio-political aspects of digitalisation (European Parliamentary Research Service, 2014; Burh and Stehnken, 2018).

Timely regulation and standards for I4.0 technologies are critical for realising I4.0. 'A standard is a document, established by a consensus of subject matter experts and approved by a recognised body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons' (International Organization for Standardization [ISO]).[19] Standards are essential for the development and dissemination of new products and services, and enable comparability and inter-operability across firms, industries, regions and countries. Since the beginning of the decade, many EU-led initiatives[20] have been implemented jointly to foster the European Standardisation System (ESS) and the single market, as essential framework conditions for industrial innovation and enhanced competitiveness. In the I4.0 era, industry-wide adoption of standards is an even more critical requirement to facilitate the global networking of production and global functioning applications, and, above all, to allow for the realisation of economies of scale and productivity gains, as expected from the adoption of new advanced technologies (Smit et al., 2016). Moreover, anticipation in the area of standards can secure the digitalisation and modernisation of EU industries. According to a recent Joint Research Centre (JRC) study, broad thematic areas for standardisation include standards for integration, environmental sustainability, quality and performance, service standards and de-risking standards (Scapolo et al., 2015).

Regulation and anticipatory regulation help cope with the pace of change induced by the transition to I4.0. 'Anticipatory regulation is an emerging method of regulation that is proactive, iterative and responds to evolving markets' (NESTA, 2017). With faster technological change, the anticipation of regulation or de-regulation is necessary to limit technical (e.g. regarding open internet) and legal barriers (e.g. on the use and sharing of data; see also OECD, 2017) and also to address obsolete regulation, IP issues and their scope, the identification of final ownership and security of data, the liability for autonomous systems, cyber-security, and labour rights and workplace conditions. As already achieved in terms of data privacy regulation (the General Data Protection Regulation (GDPR); European Commission, 2016d), the EU is expected to become even more proactive considering the uncertainties related to smart technologies, their interactions with and effects on human beings, and the current and coming data-related concerns (see, for instance, Craglia et al., 2018 on AI-related challenges; and European Commission, 2018b for recent proposals on data and public information regulations by the Commission).

The EU has taken many initiatives to foster the DSM and to facilitate the uptake of new technologies and the generation of technology-enabled products, services and processes. Nevertheless, more action and greater investment will be required to enhance the coordination and the continuity of different national strategies and to better account for industry-region-specific contexts in order to enable an inclusive and sustainable transition towards I4.0. The next section touches upon such strategies at the national and regional levels and compares the different uptake of strategies focusing on the formulation of policy objectives in the transition towards I4.0.

12.3 Stimulating, accelerating and monitoring I4.0 in the EU

12.3.1 I4.0-enabling national initiatives in the EU

A number of EU Member States have designed a strategy to address the challenges of digitalisation and the transition towards I4.0. At the EU level, these strategies are monitored by the Digital Transformation Monitor (DTM), as part of the European Platform of National Initiatives. Launched at the beginning of 2017, the European Platform aims at facilitating more inclusive coordination and best practice exchanges for the achievement of the *Digitising European Industry* (see European Commission, 2016a). It also intends to stimulate collaborations and joint investments in order to reach the critical mass required to meet the goals set in terms of digitalisation of industry across Europe. As of October 2017, 15 Member States had already launched national initiatives for the digitisation of industry.[21] Seven more initiatives were under preparation. The DTM enables an EU-level monitoring of digital transformation in order to support a coordinated EU-wide effort. The Web platform provides statistics and information about initiatives for and the challenges related to digital transformation at the EU, national, sectoral and technological levels. As an integral element of the European Platform of National Initiatives on Digitising Industry, the DTM allows us to compare the framework conditions of national digital policies, for instance, through the Digital Transformation Scoreboard (2018) (DTS). The most recent DTM report covers a total of 19 strategies and programmes for digitalisation and relies mainly on desk research and interviews. The DTS provides Country Profile Reports (CPRs) for each Member State and offers a comparative overview in terms of framework conditions, main strengths and areas for improvement, as well as interesting policy practices.

In addition, the DTM makes available on the platform the documents of individual Member State, which present the main features of national initiatives, such as the policy levers, pillars and objectives, the budget and funding models, the strengths and weaknesses, the implementation strategy, the results achieved so far and uniqueness factors. Table 12.1 uses information from these documents in order to suggest a comparative overview of some of the national initiatives.[22] While these initiatives are collected under the thematic digital transformation,[23] many Member States actually refer more or less explicitly to I4.0.

As also underlined in the DTM analyses, the initiatives present many similarities in terms of policy objectives, but differ greatly, for instance, in terms of strategy design, focus, budget and related funding mechanisms, implementation approaches, coordination mechanisms and timing in terms of implementation and results achieved so far (Digital Transformation Scoreboard [2018] and national initiatives documents). Whilst such differences limit strict comparisons across national initiatives, they provide a relevant basis for benchmarking and experience exchanges.

Often initiated by the government or PPPs, many initiatives are now led or coordinated through multi-stakeholder partnerships with the close involvement of industry, academia and research. Indeed, a majority of national I4.0-enabling policies follow a bottom-up approach for the implementation of the initiatives. Moreover, the component 'awareness raising about I4.0, I4.0-related or digital technologies' is considered by many as critical to address the uncertainties associated with the emerging paradigm and to exploit the relevant opportunities offered by new technologies. As part of their strategies for digitalisation, many Member States and regions support the implementation of Digital Innovation Hubs (DIHs).[24] DIHs are one-stop-shops for SMEs, mid-caps and more mature or established companies, which provide a range of supporting services, including technology testing, financing advice, market intelligence, training, promotion and marketing, and networking opportunities. Two hundred hubs are already fully operational and about the same number are expected to be implemented. The WATIFY campaign[25] also complements the national and regional efforts, through awareness events, success storytelling and matchmaking events, in order to stimulate the modernisation of the EU industry, the technological transformation through digitisation and the uptake of advanced technologies. Working on different timescales, such national initiatives vary in terms of what they have achieved; indeed, whilst some Member States were actually still preparing implementation plans, others were already implementing their actions (e.g. the Czech Republic, Hungary, Slovakia and Slovenia; see Table 12.1). As initiatives differ in relation to the specific targets, their achievements also take different forms, such as network development, the number of supported, funded or awarded companies, identification of experts, R&I support (funding, programmes established), research cooperation and workers' training, depending, amongst other things, on the objectives and national specific contexts and industrial structures.

Furthermore, it is becoming apparent that Member States' initiatives and programmes also differ in terms of the weaknesses and threats of the initiatives adopted. Some initiatives show some weaknesses in relation to: the lack of a clear funding model or the lack or low level of public and or private funding; the definition of implementation plans and target setting; the low business culture and inadequate or costly internet and ICT infrastructure; bottlenecks in the deployment at the shop-floor level; the balance between small and large firms; or the definition of adequate company-level monitoring indicators. Threats also vary in terms of: regional inequalities; imbalances or divergence between

Table 12.1 Overview of selected national initiatives*

Countries	*Names of the initiatives (launch, adoption or official year of announcement)*	*Broad policy objectives (examples)*	*Main targets*	*Dedicated budgets (approximate)*
Austria	Plattform Industrie 4.0 (2015)	– Leverage multi-stakeholder interests – Accompany digitisation and provide knowledge and services on I4.0 – Define fields of action and advise policy makers – Develop joint strategies with high leverage on I4.0 – Steer regional, national and international activities – Enable exchanges of experience, best practices, data and studies	Companies, research, academia, policy makers, trade unions, employees' associations	€300,000 a year from founding members and €200,000 from fees (est. 2017)
Belgium	Made Different (launched in Flanders, 2013) Made Different-Digital Wallonia (launched in 2017)	– Foster move towards I4.0 – Support digital transformation of production and operational processes – Transform manufacturing into Factories of the Future	Manufacturing companies, esp. SMEs	No dedicated funding scheme, but availability of public grants
Czech Republic	Průmysl 4.0 (2016)	– Enhance competitiveness in the wake of I4.0 – Foster ability of companies to participate in GVCs – Improve manufacturing efficiency – Improve multi-stakeholder cooperation for the development of software solutions, patents, production lines and export know-how	Policy makers, private sector, R&D organisations, industry associations, academia	No additional budget earmarked

(*continued*)

Table 12.1 Cont.

Countries	*Names of the initiatives (launch, adoption or official year of announcement)*	*Broad policy objectives (examples)*	*Main targets*	*Dedicated budgets (approximate)*
Denmark	Manufacturing Academy of Denmark, MADE (2015)	– Increase competitiveness through industrial-based research in manufacturing – Strengthen Danish technical research community – Create an enabling ecosystem for research, innovation and knowledge sharing – Optimise education for manufacturing	Manufacturing SMEs, research and academia stakeholders	€50 million for 2014–2019 from participating companies, universities, associations, private foundations and public funds
France	Industries du Futur (2015)	– Developing cutting-edge technology – Business transformation – Upskilling the workforce – International cooperation on standards and alliances – Promotion of Industries du Futur	Industry and production SMEs, mid-tier companies and technology providers, academia and public bodies	Approx. €10 billion from public sources, including IftF funding from 2017 onwards, supported by private funding
Germany	Industrie 4.0 (2011)	– Technology deployment – Integration of cyber physical systems & IoT in industry processes – Enhance productivity, efficiency and flexibility of production processes	Manufacturing and production SMEs, entrepreneurs, large corporation, Policy makers	€200 million from public and contribution from industry
Hungary	IPAR 4.0 National Technology Platform (2016)	– Enhance information exchange and cooperation – Accelerate innovation in key areas of digitalisation and production – Innovative adaptation – Fasten responses to challenges and foster bold steps towards innovation	Policy makers, private sector, R&D organisations, industry associations, universities, social circles, businesses	In progress (incl. planned state support)

Italy	Industria 4.0 (2017)	– Innovative investment – Uptake of innovative technologies related to I4.0 – Development of skills with I4.0 education programmes	SMEs, micro-enterprises and large companies	>€18 billion for the period 2017–2020
Latvia	National Industrial Policy Guidelines 2014–2020	– Align workforce supply and education to the economy's needs – Foster manufacturing in industrialised areas and reduce energy costs – Improve financing availability – Promote an innovative environment and stimulate exports	National industry, managers, employees, students, clusters, etc.	Public funds (EU and national) amount to more than €6 billion for 2014–2020, complemented by private sector financing
Lithuania	Pramonė 4.0 (2017)	– Reinforce the competitiveness and productivity of the industry – Advance the integration of digital solutions and new technologies in the national industry	Industrial companies, enterprises and universities	€79.8 million foreseen for industry digitalisation in 2017–2020
Luxembourg	The Third Industrial Revolution Strategy Powered by Transformational Investments (initiated in 2015)	– Prepare the economy and society for megatrends and disruptions and for new economic models – Foster digital capabilities and competencies – Support firms and employees in the digital transition process	Public and private stakeholders, and specific industries	Project-based
Poland	Initiative for Polish Industry 4.0 – the Future Industry Platform (announced in 2016)	– Improve competitiveness of industry and establish conditions for I4.0 – Improve competitiveness of domestic machines, devices and software – Consolidate supply chains – Improve labour market attractiveness	Public and private stakeholders, esp. SMEs and domestic 4.0 solution suppliers, academia, research	In progress

(*continued*)

Table 12.1 Cont.

Countries	*Names of the initiatives (launch, adoption or official year of announcement)*	*Broad policy objectives (examples)*	*Main targets*	*Dedicated budgets (approximate)*
Portugal	Indústria 4.0 (2017)	– Provide industry with knowledge, information and tools for transformation and empower the national workforce – Enable conditions for the development of i4.0 start-ups and national technological solutions in an international context – Make Portugal an international hub	SMEs	€4.5 billion over four years
Slovakia	Smart Industry (2016)	– Bring company closer to I4.0 principles and thinking – Strengthen the economy and support the digital transformations of businesses	Industry, SMEs, R&D organisations, education providers and civil society	No additional budget earmarked
Slovenia	Slovenian Digital Coalition (2016)	– Foster development of the digital economy – Stimulate the creation of digital jobs – Support the exploitation of opportunities of ICT and internet	Civil society, public and private sector, industry	No dedicated budget
Spain	Industria Conectada 4.0 (2014)	– Increase the industrial added value and employment – Support the Spanish model for the industry of the future – Develop the local digital solutions – Develop differential competitive levers to promote industry and exports	Industrial enterprises, esp. SMEs and micro-enterprises	€97.5 million for project calls and related programmes, €68 million for ICT firms; €10 million for innovative clusters
Sweden	Produktion 2030 (2013)	– Modernise the industry base – Support sustainable production and customised, high-end industrial services – Upskill the workforce – Facilitate investments in production R&D	Research institutes, universities and companies/SMEs from industry and services	€25 million from VINNOVA 2013–2018 and €25 million from industry

The Netherlands	Smart Industry (2016)	- Catch up with I4.0 frontrunners - Support industry use of ICT and related opportunities - Strengthen knowledge, skills and ICT conditions - Enhance industry and manufacturing competitiveness	Business community with sectoral focus	€25 million for 2014–2017 complemented by industry co-financing
UK	High Value Manufacturing Catapult (HVMC) (2011)	- Accelerate new concepts to commercial reality and create sustainable high-value manufacturing - Innovation support improving manufacturing competitiveness - Innovation support for new sectors and markets - Target innovation support to SMEs - Support the development of the next-generation technologies to transform UK manufacturing	Business, industry and research organisations	€164 million from UK government on 2012–18 For 2015/16: €79.7 million commercial income vs. €61.3 million public funding and €62 million for collaborative R&D

Source: Elaborations from the 19 country documents available at https://ec.europa.eu/growth/tools-databases/dem/monitor/category/national-initiatives.

Note: Dates of the latest versions of websites range between January 2017 and May 2018.

relevant stakeholders' interests and involvement; the insufficient reach of micro-enterprises and small companies; decreasing mobilisation; mismatches between industry needs and qualifications; the discouraging effects of I4.0 complexity; instability of funding; social rejection; cyber-security-related threats; and political and economic instability.

12.3.2 The I4.0 in Research & Innovation Strategies for Smart Specialisation (RIS3)

Under the reformed cohesion policy for 2014–2020, several regions and Member States have designed their smart specialisation strategies as the basis for the identification of priority domains for R&I investments. S3 processes unfold into six fundamental steps, including an analysis of regional strengths, weaknesses and potential; a dedicated and inclusive governance; the adoption of a shared vision for local development; the identification and selection of priority R&I areas; the design of policy mixes; and the establishment of monitoring and evaluation frameworks (Foray et al., 2012). The priority or strategic domains can be reviewed and revised, and should help regions and countries to build up or reinforce competitive advantages through the development of unique innovation niches. Ideally, priorities should foster the development of new businesses and, eventually, block easy replication or imitation outside the region (European Parliamentary Research Service, 2018). The selection of strategic domains is based on bottom-up approaches and wide stakeholder involvement – the so-called Entrepreneurial Discovery Process (EDP). EDPs intend to be inclusive and participatory processes for decision making, which bring together business enterprises, government, research and academic institutions, and civil society/consumer groups in order to identify new domains for innovation and market opportunities (see, for instance Foray, 2015). The EDP features and the implementation strategies and approaches reflect the diversity of regional and national contexts, challenges and cultures, and the selected strategic domains (see Gianelle et al., 2016; OECD, 2013).

RIS3 strategies are monitored through the Smart Specialisation Platform, which aims at providing evidence-based advice and assistance for the design and implementation of the strategies. It offers, among other things, online inventory and benchmarking tools, technical reports and experts reviews. Since 2014, more than 100 S3 strategies have been developed and more than €40 billion (and more than €65 billion including national co-financing) have been allocated to regions for priority funding through the European Regional Development Fund (European Commission, 2017b). In practice, S3 strategies are implemented by the Operational Programmes (OPs).[26] Such OPs are plans in which Member States and/or regions detail how funding from the European Structural and Investment Funds will be spent during the programming period. The European Structural and Investment Funds include the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development, and the European Maritime and Fisheries Fund.

In order to stimulate and enhance the coordination for joint projects and investments for socio-economic transformation and modernisation, the Commission has set up the Thematic Smart Specialisation Platforms (or S3 Thematic Platforms)[27] in areas relating to energy (launched in 2015), agri-food and industrial modernisation (launched in 2016). Overall, the platforms involve over 120 regions and 28 inter-regional partnerships working together with the objective of realising joint investment projects (European Commission, 2017b). The platforms are meant to be developed and led by regions relying on wide stakeholder involvement, and new partnerships can be set up through expressions of interests on the thematic platforms. In particular, I4.0 technologies are expected to play a key role in industrial transitions and modernisation across EU regions. In terms of regional scope, the S3 Thematic Platform of Industrial Modernization is expected to be crucial for further I4.0-oriented transnational and inter-regional collaborations at different stages of the R&D and innovation value chains. From this perspective, the Vanguard Initiative is seen as inspirational to develop inter-territorial spaces and organisations to reinforce industrial modernisation across EU regions in priority areas or techno-industrial domains.[28]

Originally developed as a strategic development support tool, Eye@RIS3 provides information on the priorities, including their description, economic domains and scientific domains, and EU policy objectives.[29] Data and information come from national and regional public managers and from the European Commission staff, and are updated according to the outcomes of the (continuous) EDPs. Overall, KETs and Digital Agenda feature in at least one priority for more than half of the regions. Under the broad KETs category, sub-domains include, for instance, advanced manufacturing systems and materials and industrial biotechnology (see Hegyi and Rakhmatullin, 2017 for the main evolutions of the S3P-Industry). The S3P-Industry initiative, a multi-regional partnership on I4.0, explicitly aims at showing the benefit of I4.0 solutions and technologies to SMEs.[30] As a key component of the Digitising European Industry initiative, the DIHs are also actively involved in the S3 processes, either by leading a S3 priority area or by carrying more horizontal missions.[31] Additional support to the thematic platform is provided by the EU-funded ReConfirm project through evidence-based analyses for partnerships, collaboration labs and strategic workshops (matchmaking, roadmaps making assistance, etc.).

Table 12.2 presents selected information about RIS3 for some regions with different encoded policy objectives associated with the priorities or strategic domains selected by the Member States or regions. The search terms for the selection of regions included 'industry 4.0', 'industry 40, KETs', 'key enabling technologies' and '4.0 and digital technologies' in order to flag up examples of how 4.0-related technologies have been integrated into RIS3 designs.

More detailed information about each strategy is made available by the search and selection of the Member States or regions. The scope of this chapter unfortunately does not allow us to provide a comprehensive study of the variety of I4.0-related priorities and their different implementation stages at the

Table 12.2 Examples of I4.0-related policy objectives for selected RIS3 (Eye@RIS3)

NUTS ID	*Region/country name*	*Policy objectives related to priorities*	*Date source*
BE3	Walloon Region	D – Digital transformation, D.22 – Cleaner environment & efficient energy networks and low energy computing, D.25 – E-Commerce & SMEs online, D.26 – e-Government (e.g. e-Procurement, open data & sharing of public sector information), D.27 – e-Health (e.g. healthy ageing), D.28 – e-Inclusion (e.g. e-Skills, e-Learning), D.29 – ICT trust, cyber security & network security, D.30 – Intelligent inter-modal & sustainable urban areas (e.g. smart cities), D.33 – New media & easier access to cultural contents (e.g. heritage), D.35 – Robotics, autonomous and cyber physical systems (e.g. vehicles, embedded systems) J – Sustainable innovation, J.63 – Eco-innovations, J.66 – Smart green & integrated transport systems	Dec-14
DE3	Berlin	D – Digital transformation, D.19 – Artificial intelligence, cognitive systems, augmented and virtual reality, visualisation, simulation, gamification & interaction technologies, D.24 – Digitising Industry (Industry 4.0, smart and additive manufacturing) E – KETs, E.37 – Advanced manufacturing systems	Nov-13
DK04	Midtjylland	D – Digital transformation, D.24 – Digitising Industry (Industry 4.0, smart & additive manufacturing)	Jan-16
EL11	Anatoliki Makedonia, Thraki	D – Digital transformation, D.24 – Digitising Industry (Industry 4.0, smart and additive manufacturing) E – KETs, E.37 – Advanced manufacturing systems, E.38 – Advanced materials, E.39 – Industrial biotechnology, E.40 – Micro/Nano-electronics, E.41 – Nanotechnology, E.42 – Photonics	July-14
ES21	País Vasco	B – Blue growth, B.13 – Offshore mining, oil & gas E – KETs, E.37 – Advanced manufacturing systems, E.38 – Advanced materials	Dec-14
ES61	Andalucía*	A – Aeronautics & space, A.01 – Aeronautics, A.02 – Aeronautics & environment, A.03 – Bio fuels & energy efficiency, A.04 – Remotely piloted aircrafts, A.05 – Safety & security, A.06 – Space, A.07 – Transport & logistics	Jan-14
ITC4	Lombardia	E – KETs, E.37 – Advanced manufacturing systems	Oct-14

LU	Luxembourg	A – Aeronautics & space, A.06 – Space, A.07 – Transport & logistics D – Digital transformation, D.18 – Advanced or High performance computing, D.19 – AI, cognitive systems, augmented and virtual reality, visualisation, simulation, gamification & interaction technologies, D.20 – Big data, data mining, database management … D.25 – E-Commerce & SMEs online … D.35 – Robotics, autonomous & cyber physical systems (e.g. vehicles, embedded systems), D.36 – Smart system integration E – KETs, E.37 – Advanced manufacturing systems H – Service innovation, H.51 – New or improved organisational models, H.52 – New or improved service processes, H.53 – New or improved service products (commodities or public services)	Dec-17
PL22	Slaskie	E – KETs, E.37 – Advanced manufacturing systems, E.38 – Advanced materials	Dec-12
SI	Slovenia	D – Digital transformation, D.18 – Advanced or High performance computing, D.19 – Artificial intelligence, cognitive systems, augmented and virtual reality, visualisation, simulation, gamification & interaction technologies, D.20 – Big data, data mining, database management, ..., D.25 – E-Commerce & SMEs online, D.31 – Internet of Things (e.g. connected devices, sensors and actuators networks), D.35 – Robotics, autonomous and cyber-physical systems (e.g. vehicles, embedded systems), D.36 – Smart system integration E – KETs, E.37 – Advanced manufacturing systems	Sept-15

Source: Eye@RIS3 database, December 2018.

Notes:

* Information from Draft RIS3 Document or other (otherwise from final document)
Eye@RIS3 was fully upgraded in September 2018. Data are regularly updated based on inputs from European regional and national authorities and their stakeholders.

regional level.[32] Nevertheless, as for the national initiatives, it might still be too early a stage to assess the impact of dedicated efforts to support the transition towards I.4.0. But it may not be too late to provide evidence-based and multidimensional considerations of the I4.0 readiness of EU regions in order to anticipate, for instance, a territory-specific lack of adequate resources and cost-efficient infrastructure, or obstacles to partnership, or even cases of workforce and social rejections.

12.4 Conclusions

The EU has taken several important steps and has advanced on many fronts to stimulate, coordinate, monitor and strengthen framework conditions for the uptake of digital and enabling technologies in order to accompany the modernisation of its industrial bases and systems. Nevertheless, much remains to be done to ensure consistent and sustainable I4.0-driven or I4.0-enabled socio-economic and industrial transformations. Importantly, on the one hand, the imperatives of developing a critical mass do not relate solely to target funding or infrastructure, but also, and maybe more fundamentally, to the levels of awareness and readiness of our society and citizens in relation to I4.0 technologies and their transformational potential. On the other hand, the adoption and diffusion of new technologies and models should be fast-tracked in the majority of our regions in order to considerably reduce the territorial imbalances that can seriously undermine the inclusiveness and sustainability of such modernisation and transition paths.

From a governance and policy practitioner perspective, the level of horizontal and multi-level coordination required and the limited scope for experimentation and learning pose even more complex challenges in this transition period, especially when combined with the management of increasingly open and inter-connected territories. In this context, approaches such as smart specialisation can help to address these new challenges by offering renewed possibilities for evidence-informed collaborative innovation and industrial policy making. As underlined during the European Week of Regions and Cities,[33] critical to the success of these bottom-up initiatives are the territorial competences and assets needed to generate and sustain new dynamics for value creation and capture (Bailey et al., 2018), and the ability to match policy actions with territory-specific needs.

Notes

1 Disclaimer: the analyses presented in this chapter do not necessarily represent the views of the European Commission. Neither the European Commission nor anyone acting on its behalf can be held responsible for any use made thereof. The author would like to thank her colleagues Hegyi F., Rissola G. from the Smart Specialisation Platform, Tuebke A., Hervas F. from JRC-Unit B3 and Batalla Masana M. and Engelmann U. from DG GROW for their constructive comments and feedback on the chapter.

2 The EU is a union of 28 Member States and their citizens. Many institutions are involved in decision-making processes at the EU level, including the European Parliament (elected by EU's citizens), the European Council (heads of state or governments; see European Commission, 2018b), the Council or the Council of the European Union (representatives of governments) and the European Commission, which generally proposes new laws to be adopted by the Parliament and the Council. In this chapter, the focus is on the policy directions and proposals as reflected in the European Commission's communication and documents (see Publication Office of the European Union: https://publications.europa.eu/en/home).

3 See also at https://ec.europa.eu/digital-single-market/en/fourth-industrial-revolution.

4 The Europe 2020 Strategy is the EU's agenda for growth and jobs for the decade 2010–2020. It puts forward three priority dimensions, five headline targets and seven flagship initiatives.

5 The communications of the Commission refer here to the official documents, which provide the main rationales, levers and action lines, as well as the Commission's proposals regarding a given thematic and policy area or issue.

6 The European strategy for KETs combined the efforts of different Directorate-Generals (DGs) of the European Commission, including DG Research and Innovation, DG Communications Networks, Content and Technology, DG Regional Policy, DG Trade and DG Competition, under the political leadership of DG Internal Market, Industry, Entrepreneurship and SMEs. A high-level group on KETs is advising the European Commission on the implementation of KETs. For more about the European strategy for KETs, see https://ec.europa.eu/growth/industry/policy/key-enabling-technologies/european-strategy_en.

7 In reference to Rifkin (2011).

8 Horizon 2020 is the financial instrument of the Innovation Union flagship and constitutes the largest EU Research & Innovation programme ever, with about €80 billion of funding available between 2014 and 2020. The work programme for 2014–2015 included KETs pilot lines in areas identified by the High-Level Expert Group.

9 Digital Single Market – Policies: The Fourth Industrial Revolution, https://ec.europa.eu/digital-single-market/en/fourth-industrial-revolution.

10 The European Fund for Strategic Investment (EFSI) is one of the three pillars of the Investment Plan for Europe, which finances strategic investments in key areas such as infrastructure, R&I, education, renewable energy and energy efficiency, as well as risk finance for small and medium-sized enterprises (SMEs). For more details on this, see https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/what-investment-plan-europe_en.

11 European Structural and Investment Funds: https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en. See also the early guidelines for enabling synergies between the funds at https://ec.europa.eu/regional_policy/sources/docgener/guides/synergy/synergies_en.pdf.

12 Smart Specialisation Platform: http://s3platform.jrc.ec.europa.eu.

13 Regulation EU 1301/2013. See also Foray et al (2012) for an official guide on smart specialisation strategies; and European Commission (2017b) for a recent communication on the regional policy.

14 Single Market Act I and Single Market Act II: http://ec.europa.eu/growth/single-market/smact_en.
15 Innobarometer and Business Innovation Observatory (DG GROW): http://ec.europa.eu/growth/industry/innovation/facts-figures_en.
16 Digital Economy and Society Index (DESI): https://ec.europa.eu/digital-single-market/en/desi.
17 Digital Transformation Monitor: https://ec.europa.eu/growth/tools-databases/dem/monitor.
18 Blueprint for Sectoral Cooperation on Skills: https://ec.europa.eu/social/main.jsp?catId=1415&langId=en.
19 https://www.iso.org/sites/ConsumersStandards/1_standards.html.
20 See European Commission (2016b) for ICT priority standards and the different EU initiatives in the area of standards at http://ec.europa.eu/growth/single-market/european-standards_en. See also the Vademecum at https://ec.europa.eu/growth/single-market/european-standards/vademecum_en, which compiles key documents from the European Commission on European standardisation policy and related practice. It provides guidance without having legal status.
21 See also a more detailed List of Active National Policy Initiatives for Digitisation of Industry at https://ec.europa.eu/futurium/en/system/files/ged/list_of_policy_initiatives_on_digitising_industry_across_eu_211117.pdf (last updated November 2017).
22 See https://ec.europa.eu/futurium/en/implementing-digitising-european-industry-actions/national-initiatives-digitising-industry.
23 In this chapter, policies for digital transformation are considered as I4.0-enabling policies. See Rifkin (2011) for conceptual discussions about the complementarity between I4.0 and Third Industrial Revolution paradigms in driving industrial transformation.
24 See https://ec.europa.eu/digital-single-market/en/news/digital-innovation-hubs-annual-event-2018. See also additional background information at https://ec.europa.eu/futurium/en/system/files/ged/digital_innovation_hubs_in_digital_europe_programme_final2_december.pdf.
25 https://ec.europa.eu/growth/tools-databases/dem/watify.
26 Operational Programmes adopted by the European Commission at the beginning of a programming period can be found at: https://ec.europa.eu/regional_policy/index.cfm/en/atlas/programmes.
27 Thematic Smart Specialisation Platforms: http://s3platform.jrc.ec.europa.eu/s3-thematic-platforms.
28 See https://www.s3vanguardinitiative.eu/
29 Eye@RIS3 database: http://s3platform.jrc.ec.europa.eu/eye-ris3.
30 Partnership webpage: http://s3platform.jrc.ec.europa.eu/eu/sme-integration-to-industry.
31 In practice, they can also result from an S3 process; see Rissola and Sörvik (2018) for dedicated cases studies on DIHs and S3. A catalogue of DIHs monitored by the S3 platform is available at: http://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-catalogue.
32 See, for instance, Gianelle et al. (2016); European Parliamentary Research Service (2018).
33 See the reports and presentations of the workshop session on 'Thirty Years of EU Cohesion Policy: What Works? Where? for Whom?', co-organised by DG REGIO during the European Week of Regions and Cities 2018, at: https://europa.eu/regions-and-cities/programme/sessions/154_en.

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13 Industry 4.0 and transformative regional industrial policy[1]

David Bailey and Lisa De Propris

13.1 Introduction

It can be argued that modern EU regional policy was introduced in the 1990s with the reform of the Structural Funds and the introduction of a clear set of objectives aimed at reducing income disparities across the EU via multi-level governance. This marked a shift away from a pure redistributive mechanism whereby funding was re-allocated from the richer to the poorer Member States (Bailey and De Propris, 2002) towards a bottom-up process that introduced regions as key actors in the policy-making process. Indeed, the new process enabled regions to enter into dialogue directly with the EU and meant that regions could spend EU funds on interventions that they would design and implement within an operating framework with broad objectives set by the EU and national governments.

Between the 1990s and 2013, the allocation of EU funding still had an underlying compensative rationale to the extent that the share of the allocated funding privileged low-income regions. In fact, EU regional and cohesion policies were designed to compensate low-performing and lagging regions for the possible costs they would have had to incur to cope with asymmetric shocks, whether internal or external. The introduction of the Smart Specialisation Strategy in the 2014–2020 cycle marked a further step change as EU policy became very much a growth-driven policy or a regional-level innovation policy.

As a new post-2020 cycle is dawning, one can see via DG Regio announcements that 'EU regional policy is an investment policy. It supports job creation, competitiveness, economic growth, improved quality of life and sustainable development'.[2] A decade on from the Global Financial Crisis and with austerity increasingly questioned, attention should shift to identifying clear, well-funded and achievable growth targets; however, the EU finds itself firefighting on many fronts, including Brexit, trade wars and an anaemic level of enthusiasm towards the EU encouraged by populist parties from north to south.

Against this backdrop, the EU risks underestimating the fundamental role that policy and public interventions must play just as the economy and wider society are embarking on transformations that will shape work, industry, mobility, communications and more broadly our way of life for the next 50–60 years, as has been detailed in this volume. These are times of radical and disruptive change, and inevitably – we would argue – EU regional and industrial policies must move towards having truly transformative power; this could, for example, render smart specialisation strategies with a heightened level of attention paid towards the creation and adoption of Fourth Industrial Revolution (FIR) technologies in different regions.

The objective of this chapter is to reflect on the extent to which technological change will require adjustments to EU regional and cohesion policies in order to allow the latter to have a 'transformative' power. To do so, we start by considering the evolution of EU policies in terms of vision, objectives and instruments since the 1990s. Priorities have changed over time, but, we argue, have always been underpinned by a fundamental concern for inter-regional socio-economic cohesion. The ever-present trade-off between efficiency and equity in recent EU integration (Bailey and De Propris, 2002) has often been reconciled by having declarations of a grand aspiration for growth and jobs that are then complemented by much of the funding being allocated to lagging regions to reassure the latter of the equitable nature of EU membership.

The disruptions brought about by the technologies of the FIR have the potential to introduce new layers of socio-economic divides. We will discuss if and how new technologies will widen economic divergence between low- and high-performing regions and states or, alternatively, if and how they might allow some regions to 'leap-frog' with a consequent faster catching up.

The chapter proceeds as follows: Section 13.2 discusses the evolution of EU cohesion policy over time, highlighting the shift from compensation to smart upgrading; Section 13.3 notes the effort to upgrade regional development via smart specialisation approaches; Section 13.4 summarises the scale of change coming with the FIR; Section 13.5 reviews current levels of digital disparities and considers the impact of the FIR on spatial disparities going forward; Section 13.6 issues a 'call to arms' for a transformative industrial policy given the scale of change coming; and Section 13.7 concludes the chapter.

13.2 EU cohesion policy so far: from compensation to smart upgrading

While reforms to EU regional policy in the late 1970s and early 1980s brought about minor changes and budget increases, it was the 1988 reform which essentially redesigned the entire framework of regional support. The overhaul was wide-ranging as the Structural Funds were required to make an impact on the less developed regions and countries of the EU in order to compensate them for the imbalances brought about by the completion of the Single Market (Bliss and de Macedo, 1990) and to enable them to catch up with the wealthier regions (Bailey and De Propris, 2002).

The key concern was over a polarisation of wealth and diverging growth paths across different regions: 'to ward off the threat of a two-speed Europe, the EC has reformed the structural funds. The aim is to give the weakest regions the resources to catch up progressively by making more rapid progress than the others, in spite of their handicap' (European Commission, 1992, p. 10). Following on from this change, we would argue that the rationale of EU support for lagging Member States has since evolved over time, from being redistributive at the national level (pre-1990s) to being compensative at the regional level (1990s–2013) and currently to favouring regional upgrading (2014–2020). The link between regional development and innovation became more explicit with the Lisbon Strategy, where one can read the aspirational nature of policy:

> The Union has [today] set itself a new strategic goal for the next decade: to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion.[3]

After the launch of the Lisbon Strategy in 2000, the EU pursued a growth agenda that was then reinforced by the adoption of the 'Europe 2020 Strategy' in 2010 that aimed to drive the EU towards smart, sustainable and green growth. Ever since, innovation has underpinned EU policies and especially regional and cohesion policies (which had traditionally been associated with equity priorities by reducing income disparities). Indeed, the two rounds of Structural Funds over the periods 2007–2013 and 2014–2020 have seen an increased emphasis on funding destined for research and development (R&D) and related interventions.

Since the entry of Greece, Spain and Portugal in the early 1980s, which saw a significant widening of socio-economic disparities across Member States, social and economic cohesion has been a paramount concern for EU policy makers, given the fear that deep divisions between Member States might undermine the EU project. The +12 enlargement over the period 2004–2007 and in parallel the creation of the eurozone further heightened concerns over widening inter-regional disparities. The external shock of the 2008 Global Financial Crisis hit EU Member States severely, deeply and also asymmetrically. The simultaneous processes of internal deepening and enlarging together with austerity post-2008 left some EU Member States and regions on a path of virtual zero growth for almost a decade. The result is that now, after three decades of EU intervention through regional and cohesion policies, many regions still have gross domestic product (GDP) per capita levels below 75% of the EU average.

13.3 Upgrading regions with smart specialisation strategies

The concept of smart specialisation was introduced in the late 2000s (Foray, David and Hall, 2009) as a new way of tackling regional development. Foray (2015, p. 1) proposed that 'the notion of smart specialisation described the capacity of an economic system (a region for example) to generate new specialities through the discovery of resources and competences in these domains'. The approach has become the cornerstone of EU regional and cohesion policies and has been implemented thought the Research Innovation Strategies for Smart Specialisation (RIS3) in the 2013–2020 funding round.

A number of elements of this approach are worth noting as relevant specifically for this chapter. One is the aspiration to drive regional upgrading via 'structural changes' (Foray, 2017b, p. 39) that can open up new development paths. With the term 'smart', it is suggested that RIS3 must be designed to allow regions to build on their existing specialisations by creating innovation capabilities that are compatible with such sectors. Framed as sector-specific innovation policies, RIS3 arguably re-invests governments with the task of developing capabilities that are connected with their territory, without being accused of 'picking-winners'. This idea went against the previous tendency, whereby policy makers were seen as jumping on the bandwagon of pursuing sectors that were seen as fashionable or desirable, but completely disjointed from their existing specialisations (Foray, 2015).[4] However, it is crucial to highlight that in reality, RIS3 has encouraged regions to upgrade or create a 'competitive advantage' in sectors in which they were already active rather than pursuing a true structural change.

The second element is the idea of embeddedness (McCann and Ortega-Argiles, 2015). Indeed, some form of path dependency is acknowledged whereby 'for many regions, the point is not innovating at the frontier, but rather (to) generate innovations complementarities in existing sectors' (Foray, 2017, p. 47). Smart specialisation was conceptualised at a time when the technological paradigm was known and consolidated. The adoption and multiplication in countless incremental variants of the dominant technologies in different sectors and regions were perceived as crucial keys to unlock some form of *specialised diversification* (McCann and Ortega-Argiles, 2015) in regions that were lagging behind or underperforming. Smart specialisation also drew upon a well-established literature that understood the systemic nature of innovation with its spatial and connected prerogatives. In order to do this, it endorsed reliance on delivery infrastructures such as regional innovation systems with their triple helix approach.

The third element to note here is the process of entrepreneurial discovery that would motivate firms and institutions to explore and experiment with different interventions over what opportunities might arise (Foray, 2015). The novelty here is to envisage that policy makers have the ingenuity and risk-taking outlook – as well as the institutional capacity[5] – to explore and experiment with policy objectives and tools. In other words, policy design and implementation requires some entrepreneurial spirit not only from firms, but also from other key stakeholders in the regional system of innovation, underpinned by what Foray (2015) calls entrepreneurial knowledge that can reside not only within businesses but is also dispersed systemically.

So, in terms of regional policy, smart specialisation has been used to emphasise the need to exploit related variety, build regional embeddedness and enable strategic diversification. This relates to a final feature, notably the need for regional actors (government, firms, universities, research institutions, etc.) to collaborate, recognising the current starting point for the region in terms of skills, technologies and institutional governance, and then to build on these capabilities rather than trying to start 'from scratch'.

This approach sees the capacity of territories to root their economic activity in the local institutional fabric as being central to their economic success, through the generation, acquisition and exchange of knowledge. Yet such knowledge is uncertain and is embedded in localities; this needs to be uncovered through participatory and bottom-up processes to build consensus and trust (Barca et al., 2012). This place-based smart specialisation approach has strong parallels with Rodrik's (2004, 2008) perspective of industrial policy as a process of discovery requiring strategic collaboration between the private sector and state in unlocking growth opportunities, but set within a framework of multilevel governance so as to enable a process of local collaboration and discovery.

In this vein, industrial and regional policies which facilitate a process of discovery through strategic collaboration are seen as relevant under smart specialisation perspectives and require appropriate institutions to engender this. In fact, this is largely how modern, intelligent industrial policy design is conceived of in contemporary debates (see Rodrik, 2004, 2008), with industrial policy ideally having the quality of 'embedded autonomy', whereby it is not captured by firms and sectors, but where, as noted above, it focuses on the discovery process, where firms and the state learn about underlying costs and opportunities, and engage in strategic coordination. Given the uncertainty generated by the FIR and the need for a process of knowledge discovery, we will return to policy implications below.

13.4 Technological change and the FIR

As has been stressed throughout this volume, a wave of new technologies is arguably driving a shift in our techno-socio-economic paradigm (Perez, 2010). Indeed, these technologies are expected not only to change the organisation of production inside and between firms, as well as the balance between capital and labour, but to fundamentally change the workplace, the physical environment and the way we live our lives. There include artificial intelligence (AI) biotech, nanotech, neurotechnologies, green and renewables, information and communications technology (ICT) and mobile tech, cloud technology, big data, 3D printing, the Internet of Things, robotics, sensoring, space technology and drones.

The introduction of these technologies was first noticed through a debate in the late 1990s and early 2000s on the importance of general purpose technologies (GPTs) and key enabling technologies (KETs). As the name suggests, GPTs are those that can find a myriad of applications across different sectors and markets (Bresnahan and Trajtenberg, 1995). These have included nanotechnology and biotechnologies, ICT and the internet. On the other hand, KETs 'act as a platform for the diversification of firms' competencies into a broader set of technologies fields' (Corradini and De Propris, 2017, p. 198); in other words, KETs tend to be multi-disciplinary to the extent that their adoption can generate technologies that in turn can feed into diverse applications. These include micro-/nano-electronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies.[6] Some of the current debate on the FIR (Rifkin, 2011) suggests that these new technologies are indeed KETs. Certainly, there is little doubt as to their pervasiveness and disruptive potentials.

13.5 Current levels of digital disparities

Much of the literature on the impact of technological change on socio-economic disparities has focused on IT first and more recently on internet and digital technologies. Serious concerns have been raised about the risk of so-called *digital divides* (OECD, 2001) which could emerge between regions in the same country, between countries and, more crucially, between the rich and poor in society (Hundley et al., 2003).

We focus in this chapter on cross-country divides that technological change can trigger. The EU has always been concerned with income disparities – as mentioned above – but there is evidence that these can in turn underpin broader variations in terms of access to and adoption of technology, which can subsequently result in wider socio-economic disparities.

There are many factors that can cause digital divides and these include differences in human capital and human capital development, infrastructural capabilities, institutional set-ups and policy, access to finance and culture (including attitudes to risk and failure) (Hundley et al., 2003). Going forward, knowledge will matter more than ever in relation to understanding and using new technologies. However, knowledge is embedded in people and for this it is uneven, cumulative and sticky. Human capital endowments will give some places advantages that others will not have; equally, knowledge will age quicker than before, so human capital development cannot stop with education, but must stretch into lifelong learning, training and retraining.

This takes us to the second discriminating factor, i.e. that infrastructural capability includes education and innovation systems. These again can vary greatly in terms of quality and content, although the EU has made huge progress in aligning qualifications to enable frictionless labour mobility across EU Member States. The EU has favoured the conservation of national and regional institutional set-ups and policy frameworks that reflect the peculiarity of Member States. This was very much endorsed by the subsidiarity principle adopted as a cornerstone of the reform of Structural Funds. This means that the mechanisms for change that are driven by policy and institutions also vary greatly. In terms of access to finance, for example, firms face a more similar landscape; indeed, according to Hundley et al. (2003), the EU overall lacks risk capital that enables the formation of new and innovative firms, especially at times of high risk, such as when technology is changing – this goes hand in hand with an overall more risk-averse attitude in the EU than the US for instance (ibid).

Some evidence presented below will show that EU Member States and regions present clear divides and that a major issue for EU policy makers is the extent to which technological change will lock regions into some path-dependency development that will ultimately exacerbate such cleavages. Indeed, recent evidence from the EU Regional Innovation Scoreboard confirms that when considering aggregate innovation inputs and outputs, certain innovation leaders and laggards across the EU can be identified. Here we take two indicators to sketch the complexity of the situation. If we look at the number of firms across EU Member States that employ ICT specialists as a proxy for *digital skills*, a clear divide emerges between northern European countries and southern and eastern ones (see Figure 13.1). Equally, considering the level of automation and digitalisation in the production process, the evidence shows that countries characterised by industries reliant on scale economies and that are therefore larger in size, such as Germany, tend to have a greater number of enterprises whose business processes are already automatically linked to suppliers/customers. This can of course deliver greater efficiency and labour productivity (see Figure 13.2). Finally, the degree of digital penetration can be measured by people's digital skills; however, data shows that the picture is quite different; core EU countries show much less digital dexterity than Italy, Spain, the UK and the Scandinavian economies (see Figure 13.3). The reasons for this might be manifold, including the extent of infrastructural investment and societal readiness.

13.6 Towards a new, transformative industrial policy?

The scale and speed of the challenge posed by the FIR brings into focus both the need and possibilities for a broader canvass on which to draw transformative industrial and regional policies approaches. Space constraints preclude exploring this in detail in this chapter, but this could include, for example, fostering regional industrial policy as a process of discovery so as to identify opportunities and challenges and ways to overcome such challenges (Rodrik, 2004, 2008), new forms of technology policy to ensure that the 'general purpose' nature of new technologies reaches different sectors and regions, skills and (re)training policy, access to finance and support for small and medium-sized enterprises (SMEs), policies to support 'reshoring' as global value chains change and so on.[7]

Firstly, on training, the FIR will see AI and automation both destroy jobs and also create new ones (see World Economic Forum, 2018). This raises a profound risk of further labour market polarisation, and there will be a need to not only develop the skills required for the FIR to be applied in different sectors and regions, but also, as noted above, a need to develop more of a lifelong approach to training and retraining throughout workers' careers. On this, European countries and regions might learn from successful experience elsewhere, such as in Singapore with its 'Skills Future' programme, as well as regional examples in the EU itself. An instructive example is industrial policy since 2015 in Emilia-Romagna, particularly through its 'Patto per il Lavoro' (Pact for Employment and Growth) (Bianchi and Labory, 2018). The Pact lays out a long-term vision

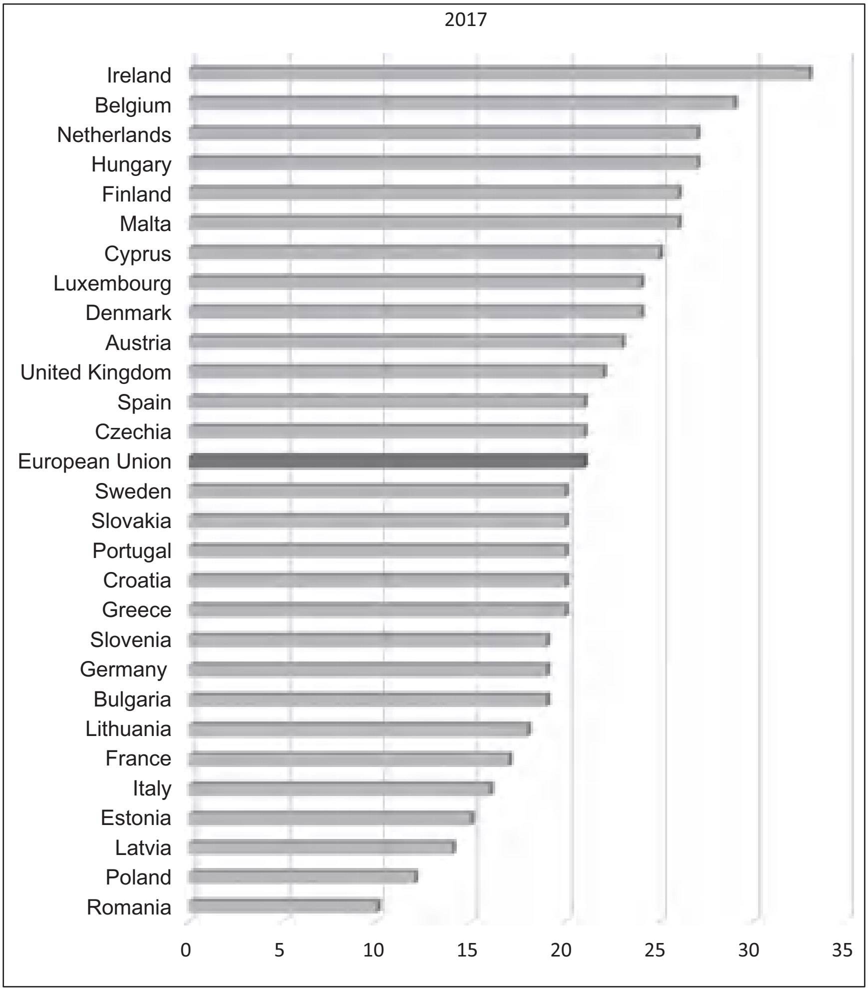

Figure 13.1 Enterprises that employ ICT specialists (% of enterprises).
Source: Authors' elaboration from EUROSTAT.

for regional development, comprising a shared understanding of challenges and a joint approach to foster investment, growth and better jobs, with interventions to leverage the region's strategic assets.[8]

Secondly, and picking up form earlier discussions, on technology policy, policy makers will have to nurture and engage with ecosystems of open, interconnected networks of stakeholders, cooperating to a much greater extent through strategic partnerships (Bachtler et al., 2017). Such ecosystems will be more dependent on their business environments to source knowledge regionally

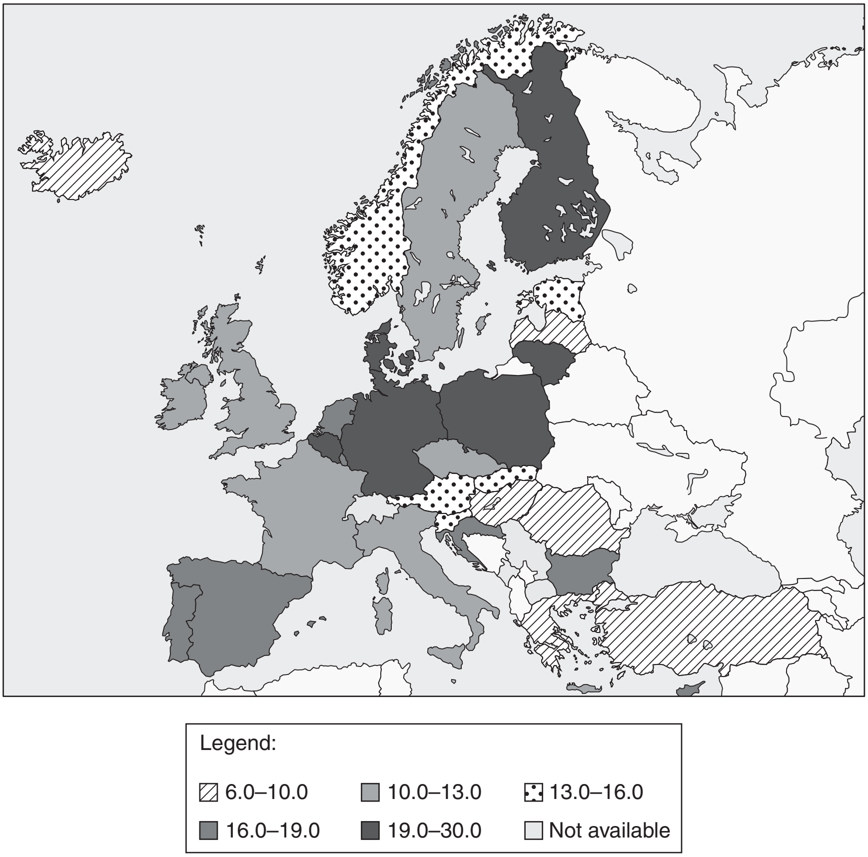

Figure 13.2 Enterprises whose business processes are automatically linked to suppliers/customers.

Source: Authors' elaboration from EUROSTAT.
Note: Enterprises with at least ten employees, NACE sectors, 2009–2017.

and internationally. A number of factors are relevant here for value creation and capture in ecosystems as Bailey et al. (2018) highlight.

Thirdly, the rapid pace of technological and other changes inherent in the FIR pose considerable uncertainty and risks for firms and governments alike (Andreoni and Chang, 2016). Managing this calls for the pooling of resources and risk-sharing, and requires the use of joint support services and infrastructures. On this, Bachtler et al. (2017) highlight, for example, 'living-labs' where multi-national companies and start-ups can interact and benefit from each other's competencies. Such ecosystem support needs to be regionally provided, but positioned within a multi-level governance framework, and to be able to integrate with innovation systems internationally. Moreover, as

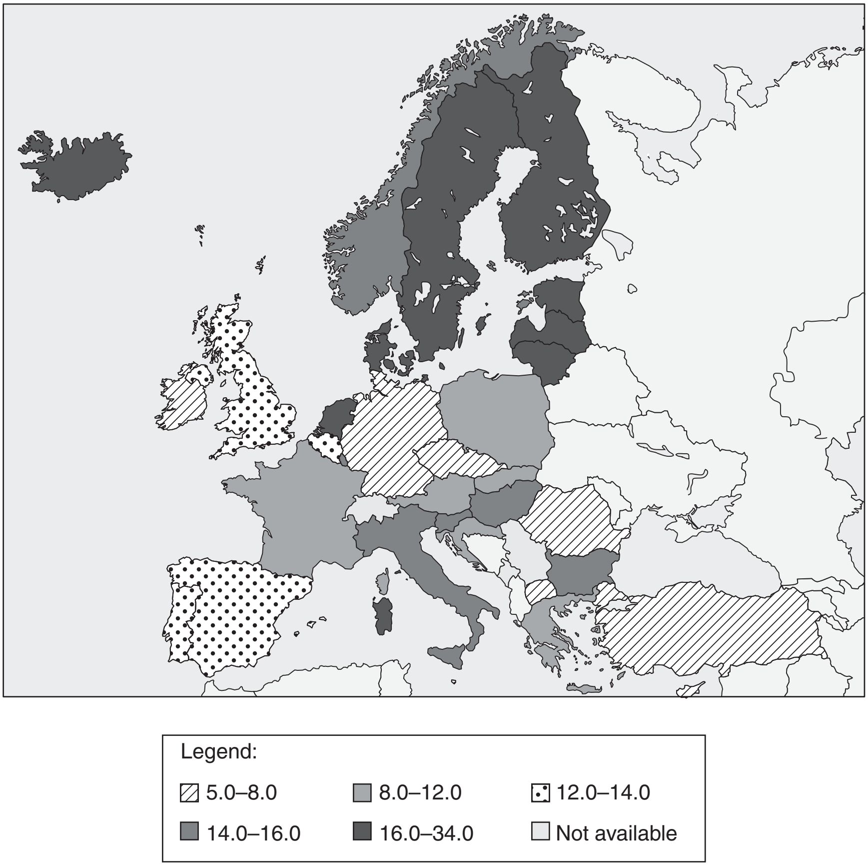

Figure 13.3 Internet skills (individuals who have carried out five out of six internet-related activities).

Source: Authors' elaboration from EUROSTAT.

Notes: Internet skills are measured using a self-assessment approach, depending on how many internet-related tasks have been carried out, without these skills being assessed, tested or actually observed. The internet-related tasks are as follows: used search engine, sent mail with attachment, posted messages to chatrooms/newsgroups or online discussion forum, made phone calls, done peer-to-peer file sharing or created a webpage. Individuals' ages 16–74. Year 2013.

Bailey et al. (2018) stress, these need regular reviewing to ensure consistency with regional needs.

Fourthly, disruptive innovation often requires inter-disciplinary approaches and 'open' models of collaboration (Chesbrough, 2003). As the OECD (2016) has noted, 'pieces of knowledge required come from various actors and activities are rarely available inside a single organisation … it is important therefore to support the generation, diffusion and use of many sorts of knowledge and types of collaboration' (OECD, 2016, p. 68). For this 'mixing' to occur, an open and collaborative environment is needed, built on established relationships and trust. This in turn highlights the need for well-developed institutions capable of nurturing collaboration and networks both regionally and internationally (Amison and Bailey, 2014) and, in industrial policy terms, in bringing actors together in the knowledge-discovery process.

Finally, as global value chains change and small-scale production possibilities emerge once again closer to innovation, there may be scope for industrial policy to help 'repopulate' manufacturing ecosystems in the UK and Europe. Recent research, for example by Bailey et al. (2018) looking at 'home sourcing' in Spanish manufacturing, suggests that policy may well have a role to play, but not in trying to bring back labour-intensive activities (these will in any case be susceptible to wage rate and exchange rate shifts, and footloose in nature as relative unit labour costs shift). Instead, recent Spanish experience suggests that activities undertaken by R&D-intensive manufacturing firms producing non-standardised products are more likely to be reshored (ibid.). This would suggest that reshoring is unlikely to re-create large numbers of manufacturing jobs (in line with the work of De Backer et al. (2016) and Bailey and De Propris (2014)), and certainly not low-skilled jobs that have been offshored or outsourced abroad. In addition, while reshoring as global value chains change is indeed a real opportunity, it is not a foregone conclusion, as its actual logistics can be challenging (Bailey and De Propris, 2014). Whether reshoring benefits mature EU regions will depend, *inter alia*, on the availability of skills, innovation capacity, the supply chain base, support services and the role of institutions. Maintaining an ecosystem of firms and agencies provides firms with a 'deal-breaking' anchor, making home-sourcing a viable option (this correlates to the US and British reshoring experience; see Bailey and De Propris, 2014).

13.7 Concluding comments and policy recommendations

To conclude, policy interventions should form part of a more holistic industrial strategy for stimulating business investment and new firm formation to rebuild value creation and capture, and safeguard manufacturing ecosystem competitiveness. Policy needs to take this on board, for example, in private–public-sector dialogue to identify opportunities to rejoin supply chain functions. This would be in line with modern conceptions of industrial policy as a collaborative process of discovery of information involving the public and private sectors.

As the FIR will play out differently across sectors and regions, this will have implications for the focus and innovation aspirations of EU cohesion policy. The integration of sectors with new technologies will be fundamental in allowing the former to be truly transformed in the light of the new technologies. A transformative industrial policy therefore needs to 'join up' technologies, sectors and places. The challenge for the new round of RIS3 will be to acknowledge the transformative necessity of policy intervention as against a more incremental upgrading.

A transformative industrial policy needs to think beyond sectors alone and instead identify, nurture and diffuse the key cross-cutting technologies (e.g. digitalisation, the Internet of Things, robotics and AI) that have an enabling role across manufacturing and services. Linked to this, industrial strategy needs to recognise and exploit such technologies by making them accessible to businesses in different regions. Furthermore, a transformative industrial strategy needs to be developed both nationally and regionally in a holistic sense (for example, on skills, access to finance, clusters, supply chains and innovation) so as to enable policy to be better suited to the distinctive characteristics and advantages of different scales. This could entail examining what a regional industrial strategy might look like, identifying sectoral trends, analysing emerging strengths and opportunities identified, and carrying out analysis of the export potential of key sectors in which the region already holds emergent strengths and which can be built on in a 'smart specialisation' sense.

Such an approach requires regionally based industrial development strategies promoting 'related diversification' capitalising on the FIR. Such strategies need to recognise: (i) the need to bring together different but related activities in a region via cross-cutting FIR technology platforms (such as via living-labs or digital demonstration hubs); and (ii) the differing potentials of regions to diversify, due to different industrial, knowledge and institutional structures linked to specific regional historical trajectories. Rather than 'starting from scratch' or applying 'one-size-fits-all policies', regional industrial strategies for the FIR instead require tailor-made policy actions embedded in and linked to the specific needs and available resources of regions, starting with the existing knowledge and institutional base in that region. These need to capitalise on region-specific assets rather than attempting to replicate and apply policies that may have worked in quite different places (Bailey et al., 2018).

However, to transform the region's potential based on 'unrelated variety' and to broaden and renew the region's industrial structure by helping it branch into new related activities, policy could encourage crossovers between manufacturing (and service) industries and between manufacturing and new technologies. This could come via knowledge transfer mechanisms that connect related *and* unrelated industries (see Grillitsch et al., 2018), such as by: (i) enhancing entrepreneurship from unrelated industries (targeting such entrepreneurs would not only increase the likelihood of successful policy, but could also contribute to regional diversification); (ii) encouraging labour mobility between related and unrelated industries, as it transfers knowledge between industries and may lead to new 'recombinations' of knowledge (such labour mobility could also increase the level of human capital, as firms and employees learn from experience in related sectors, and in turn could help regional resilience as workers can move between sectors); (iii) promoting exposure to new technologies via institutional intermediaries; and (iv) supporting collective research collaboration with partners from related and unrelated competences (ibid).

Other elements would involve, *inter alia*, the need for: new skills to be developed and constant reskilling and upskilling processes as the FIR progresses; enabling SMEs to have access to funding and finance to embrace digital technologies; recognising and exploiting possibilities to reposition firms, industries and regions on new parts of the global value chain as the value added of manufacturing changes over time; seizing reshoring opportunities as relocalisation opportunities open up, involving policies to rebuild supply chains in Europe; infrastructure investment to embrace new technologies (e.g. 5G) and so on as part of a holistic regional industrial policy.

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Notes

1 This chapter builds on and develops the discussion in Bailey and De Propris (2019).
2 http://ec.europa.eu/regional_policy/en.
3 www.europarl.europa.eu/summits/lis1_en.htm.
4 The term 'specialisation' is in a sense misleading as 'smart diversification' better represents this line of thinking.
5 This can be challenging. Relating to the earlier reform of the structural funds, for example, Bailey and De Propris (2002) stressed that the 1988 reform of the EU Structural Funds gave EU regions an entitlement to participate in the design and implementation of regional policy, but that some of the weakest regions lacked the institutional capacity to actually access and implement the funds allocated to them. Regional inequalities subsequently increased and only later started to narrow. Only after a process of institutional capacity building and learning were some regions able to interact with the European Commission and national governments on regional policy issues, and only then where gatekeeping Member States allowed it.
6 http://ec.europa.eu/growth/industry/policy/key-enabling-technologies_en.
7 In the context of the FIR, this could involve more radical forms of change, including path diversification and path change (see Grillitsch et al., 2018).
8 On some lessons from Germany's training system being applied internationally, see Wiemann and Fuchs (2018).

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