5 Industry 4.0

Transforming local productive systems in the Tuscany region

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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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