1 Disruptive Industry 4.0+

Key concepts

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1.1 Introduction

Innovation matters and the process of creating new knowledge that can be translated into innovations drives the competitiveness of firms, industries and places. Our analysis starts with a critical overview of the dynamics of technological change and the impact on the economy and society; drawing on the idea of a ‘techno-economic paradigm’ (Perez, 2010), we try to unravel the breadth and depth of the transformative impact one must expect from the technological change brought about by the Fourth Industrial Revolution (FIR). A host of new technologies is triggering economic and social change: both shift the techno-socio-economic paradigm of the economy and society. Notably, technological change disrupts the organisation of production and the use of production factors (labour and capital) and consumption. We introduce the idea of Industry 4.0+ as the deployment of all the technologies of the FIR that will trigger a transformational shift in the techno-socio-economic paradigm attuned to a green economy and society. This needs to be recognised as a key part of any effort to deliver inclusive socio-economic growth.

1.2 Technological change

A new wave of technological innovations has started to fundamentally alter how we make things, and it signals the start of an era of huge change. To fully understand this, it is worth starting from the idea of Kondratiev’s long waves (Kondratieff and Stolper, 1935). The idea of Kondratiev’s waves is that after a certain period of time (he found about 50 years), technologies exhaust their potential for new ideas to boost the economy; they slow down until a critical mass of new technologies comes into fruition all at once. This then kicks off a new technological wave that is able to trigger a spate of new applications in new processes and new products (ibid). Kondratiev suggested that radical inventions could revolutionise the techno-economic nature of economies. Indeed, the subsequent spawning of countless minor and incremental innovations could penetrate every aspect of the economy.

Such technological waves linked technological change with cycles in the global economy. Kondratiev saw such major cycles as driven by endogenous forces that therefore unravel organically. The endogeneity of the cycles conceptualised by Kondratiev (1979) drew on the work of Schumpeter (1942), who argued that although technology was exogenous to the economy, it was endogenous to the technology from which it was generated. Indeed, technology was argued to be path-dependent and the translation of inventions into innovations that were economically viable was endogenous to the environment and proceeded along what Perez (2010) called a 'deployment trajectory' where incremental innovations spawn from radical innovations. Kondratiev's waves have been consequently criticised in the methods underpinning the marking of cycles, but have remained widely accepted as a way of capturing the economy as a dynamic process that can be described with major cycles of 'transformation in the productive forces' (ibid, p. 23).

Whether technological change is evolutionary (for instance, Isaacson, 2014) or revolutionary (Kondratiev, 1979), there seems to be break-points that mark the introduction of new technologies whilst old ones are still being phased out. Such technological breaches therefore crack the dominant technological paradigm with a disruptive force that undermines its usefulness and desirability. The systemic transformative change in the economy and society comes from endless incremental innovations and applications derived from such new technologies.

Technological change is somewhat endogenous, in the sense that its roots are in the techno-economic system itself. Truly disruptive changes tend to be technology pushed: this means that long gestation periods might be inevitable before a switch is triggered and ultimately a new techno-economic paradigm takes over. Indeed, the incomplete exploitation of existing – albeit mature – technologies confirms to firms the continued presence of profit-making opportunities in untapped markets and prevents them from taking the risk of investing in new technologies which might still lack 'proof of concept' or clear market-ready applications. The apathy and risk-aversion of demand also delay the translation of inventions into innovations and new products and processes.

The strategic accumulation of inventions culminates in a disruptive technological breakpoint when the economy experiences what we call a 'technological limbo'. This is a status where a mature technology has mostly exhausted its applicability and its leverage on productivity gains, as well as having shown constraints and drawbacks (see combustion engine technology and pollution, for instance), whilst at the same time, a suite of new alternative technologies are emerging without any of them standing out as clear winners. A technological limbo occurs when technologically pushed inventions that were brewing in the background start challenging the existing mature technology, although ignored by the economy which is still occupied with exhausting incremental innovations.

Revising the conceptualisation of Kondratiev's waves with Perez (2010), we pinpoint the existence of the phase that we call a technological limbo to be the trigger point of the new technological revolution which then unfolds with

an exploration phase before accelerating to finally reach a maturity phase. The exploration of what new technologies can do occurs with the introduction of radical changes leading to the consolidation of a new paradigm defining a new technological trajectory, which then peaks when the dominant technology shows signs of constraints. The passage between the old and new technology of course encounters great resistance from the incumbent technology adopters, together with the inertia of the production and consumption systems attached and accustomed to the incumbent technology.

This technological limbo is exited when the new technology starts being assimilated by the socio-economic system; namely, when risk-taking entrepreneurs develop and take to market new products that experimental consumers start buying, or when new processes are designed and developed that firms adopt and test before being rolled out as a standard. Connected and unconnected inventions result from the creation of new knowledge or experimental and experiential discoveries.

Tracking the deployment of a technology trajectory with its impact on long-term growth, the exploration and adoption stages are those where we can argue the economy benefits the most. The impact of new technologies on growth depends not only on changes to production, but crucially on changes to the techno-economic paradigm that Perez (2010: 194) defines as ‘the way socio-institutional structures are organised’. Only the acceleration of technological adoption together with the adaptation of demand, consumption and use of new products, practices and routines can allow for the full exploitation of the growth potentials associated with a new wave.

The disruption of new technologies in each wave fundamentally changes which resources are used and how they are used, as well as reshaping the organisation of production. New sectors are created while others become obsolete. This dynamism resets the economy and sparks growth again. Economic change is followed by equally profound changes in consumption, use and access to markets, as well as in ways of life. This is why we argue that each wave ushers in disruptive change to the economy and society.

However, the impact of technological change on (sections of) society is costly. For example, we can note the following: changes in the labour market due to new skill requirements in the economy can cause a skills gap and skills obsolescence, leading to unemployment and polarised labour markets; new products can alter daily consumption habits and choices as well as the provision of services; and new forms of business and new markets can sharpen a digital divide, leading to consumption exclusions.

The social cost of the initial shock will flatten out when the socio-economic system starts a process of adaptation to the new technologies that culminates in all aspects of society embracing the myriad of incremental innovations that new technologies are translated into. At this point, the economy and society are locked into what will become the dominant technology (see Figure 1.1).

In summary, when deployed, new technologies will disrupt the economy and society, ushering in a new techno-socio-economic paradigm.

Figure 1.1 Technological change.

Source: Authors' adaptation from Perez (2010).

1.3 Technological revolutions

Tying into the argument that technological change occurs in waves, there have been a number of important contributions that have recently elaborated on the nature and timing of the technological change that is now unfolding. Whilst agreeing on their revolutionary underpinnings and making a case for a series of *technological* revolutions triggering concomitant *industrial* revolutions starting from the first appearance of automation and steam power in the late 1700s, the different contributions fundamentally disagree on how many *revolutions* there have been.

The main reasons for this difference lies on the definition of revolution. In one of the first publications on this topic, Perez (2010) make a robust case for there having been five technological revolutions, on the basis that each marks a shift in the techno-economic paradigm that introduces new key inputs, new sectors, new organisational models and new profit opportunities. Indeed, if '[n]ew technology systems not only modify the business space, but also the institutional context and even the culture in which they occur' (Perez, 2010: 188), then she argues that the first appearance of automation with the spinning machine in

the 1700s needs to be separate from the introduction of steam in the 1800s. Merging the latter two into one wave led other contributions to suggest that one can record four main industrial revolutions, starting with Rifkin (2011) and Berger (2014), in parallel to GTAI (2014); Deloitte (2015); Siemens (2015); the EU Parliament (2015); McKinsey (2015); and the EU Commission (2016). Breaking ranks, the OECD (2017a) and Marsh (2013) refer to the next production revolution as the new industrial revolution.

A first wave of technological change in contemporary history starts with innovations related to steam power, cotton, steel and railways, coupled with mechanisation and the surge of the factory system. This marked the ‘first’ industrial revolution between the last decades of the eighteenth century and the first half of the nineteenth century. Cottage industries were dwarfed or replaced. Industrial districts (Marshall, 1923) were often seedbeds of those developments, even if progressively challenged by the increasing importance of economies of scale in bigger factories, leading to the industrialisation of rural spaces and the emergence of industrial cities and regions.

The Second Industrial Revolution was triggered by the introduction of electricity, heavy and mechanical engineering and synthetic chemistry in the second half of the nineteenth century. This spanned a few decades until the arrival of oil and the automobile. New sectors emerged, not only those related to the automotive systems, and others were given a different identity, as in the case of many consumable goods with the consolidation of the large-scale production model. Standardised demand was satisfied by mass production thanks to internal economies of scale. Even more complex business forms, such as multinational firms, developed.

The Third Industrial Revolution was prompted by innovations in electronics and computers, petrochemicals and aerospace, together with demand becoming more volatile in many sectors in the last decades of the twentieth century. Mass markets broke up and more flexible organisational forms such as firm clusters and industrial districts became pivotal points for development, thanks to their flexibility and innovation. At the same time, new technologies enabled faster communications and transport that pushed and accelerated a process of globalisation in production, commerce and socio-cultural integration.

1.4 The Fourth Industrial Revolution

The conceptual framework above helps us to understand the breadth and depth of the transformative impact that must be expected from the current Fourth Industrial Revolution (FIR). A host of new technologies that started being developed in the mid-1980s is driving a wave of change in a new emerging techno-economic paradigm. These new technologies include: biotech, nanotech, neuro-technologies, green and renewables, 16 information and communication technologies (ICT), and mobile tech, 3D, artificial intelligence, robotics, sensing, space technology and drones.

A cluster of new technologies and sectors rapidly evolved from such a basis and are now driving what is seen as a fourth revolution. The embryos of some of these new technologies can be traced back to the mid-1980s, but to witness their impact on production and sectors, we had to wait until the turn of the century. This current wave is creating a completely new production model inside the factory and between firms. It is already referred to as 'Industry 4.0', 'Manufacturing 4.0' or 'smart manufacturing'.

Four main changes capture the emerging manufacturing model. Firstly, digital technologies are increasingly adopted throughout the production process, and between producers and customers. Inside factories, intelligent machines will enhance both the productivity and the flexibility of productions that will deliver 'mass customised' products. Between firms, digital technology will enable the integration and orchestration of distant machines along the value chain. There is a palpable concern that the combined effect of digitalisation and robotisation will alter the balance between labour and capital inputs, with inevitable consequences for jobs, wealth distribution and societal equity.

Secondly, new pathways to value creation will be activated. In particular, 'servitisation' is the symbiosis between traditional manufacturing sectors with services, whereby the value to the customer is no longer associated (only) with the ownership of the product itself but also with the services that enable the enjoyment of the product's intrinsic functions. Customers are therefore buying services together with the product, or even the service that the product provides, rather than the product itself. Servitised products already exist in some industries such as aerospace; however, the extension of this model to a wide set of goods thanks to the opportunities opened up by digital technologies and the rate of introduction of new offers requires a fundamentally different business model for the firms.

Thirdly, some of the new technologies lend themselves to efficiently scaling down productions, opening up new opportunities for small producers which can tap into market niches for personalised, customised and innovative products. These need to be produced in small batches or even as unique pieces. Such niche markets require customers to co-innovate or even co-produce with the manufacturer or the maker. Digital communications and 3D printing technology, for instance, enable innovators and inventors to again become manufacturers, as was the case during the First Industrial Revolution, and to connect directly with markets. Closer interaction between innovators, manufacturers and customers translates into more distributed manufacturing, whereby customers source or commission the making of products locally.

Finally, almost all new technologies can be deployed to enhance the environmental sustainability of production processes and consumption via energy saving, bio-based products and fuel, remanufacturing and reusing of components.

For our purposes, there is one important point that is worth making. Each wave of technological change is the outcome of scientific exploration inside and across disciplines, leading to breakthroughs in the propositional knowledge we have of our world and in extended parts of prescriptive knowledge.

Its effects ripple across the economy through a myriad of channels and over time: technological change will alter the organisation of sectors and places, institutional frameworks and consumption models, as well as the distribution of wealth, income and jobs across regions and classes. The awareness, access to and adoption of such new technologies on behalf of firms and systems will vary depending on their internal capabilities and processes. Inevitably technological changes will tend to be perceived as exogenous shocks by firms, industrial districts, production and socio-economic systems. The last wave introduces a complete new array of knowledge whose usefulness and applicability are still to be fully revealed.

1.5 The current debate on Industry 4.0

This widely used term has already been defined in a number of different ways by think-tanks, business leaders, international organisations and policy makers. Advanced economies as well as manufacturing-intensive economies such as China have also identified how it would apply in their own context. This section critically overviews the recent and current debate on a new manufacturing model that is at the moment understood to fall under the concept of Industry 4.0.

The term was coined in Germany in 2011, when the Federal Government launched a project in relation to industry-science partnerships called *Industrie 4.0*. It described the impact that the ‘Internet of Things’ was going to have on the organisation of production thanks to a new interplay between humans and machines and a new wave of digital application to manufacturing production. The German government (GTAI, 2014) made *Industrie 4.0* its high-tech strategy to be delivered through a concerted effort of key national stakeholders such as industry associations and *Fraunhofer* Institutes.

The main motive for this drive to increase production efficiency is due to the nature of sectors and the composition of German industries. Germany has developed a competitive advantage in the engineering, machinery, equipment and auto sectors. These are historically able to capture and maximise labour productivity with process innovations that have included mechanisation and more recently automation. These sectors also present an efficient minimum scale, so firms are medium to large-sized. After a long period of a favourable euro regime, Germany has accumulated a large trade surplus, especially with emerging economies. Nevertheless, this has started to be squeezed by the very same Asian economies (South Korea and China) which have now started to compete in the same markets. *Industrie 4.0* has therefore been a deliberate strategy to enable German manufacturing firms to maintain high productivity levels in their factories in order to continue exporting mechanical engineering products and equipment (e.g. auto and machinery), as well as to build capabilities to export the very same ‘efficient factory model’ underpinning their competitive advantage. Indeed, Deutsche Bank (2014) suggested that Germany’s adoption of *Industrie 4.0* was to become the ‘factory outfitter of the world’.

A number of initiatives emerged from this such as the *Industrie 4.0 Platform*, *SmartFactory* and the technology network called *it's OWL*. Such policy endorsement triggered a buzz amongst manufacturing business leaders, who then started to circulate the term to suggest that a new generation of digital technologies was capable of redefining the use and role of a new generation of machinery. The introduction of these machines was argued to transform the factory and inter-factory supply chains in cyber-physical spaces thanks to cloud computing, the Internet of Things and automation. The opportunity presented itself when some German multi-national firms – already adopting advanced technology and literally on the technological frontier – saw this new wave of innovations coming to fruition.

Captured by a business-focused narrative, *Industrie 4.0* started being celebrated for the impact it was expected to have inside the factory, as mentioned above. New technologies such as the Internet of Things, AI, robotics and automation were all argued to bring greater efficiency, productivity, responsiveness, flexibility and ultimately seamless integration of the supply chain into manufacturing production (Deutsche Bank, 2014).

Efficiency was mostly understood here as cost-efficiency, energy-efficiency and labour-efficiency, often summed up by the futuristic idea of 'light out factories' with no lights and no heating (*Wall Street Journal*, 2002; Heng, 2014). Factory automation leading to job polarisation and job obsolescence is emerging as a main challenge (Cowen, 2013; Brynjolfsson and McAfee, 2014). Increased productivity would come from automation enabling more flexible processes, shortened lead times, better control of the value chain flow and better quality control. Responsiveness would be greatly enhanced by the data collected thanks to cloud computing. Data can be collected during production on site and along the supply chain, as well as from consumers and users. Data provides information and feedback to be used to enhance processes and responses. Linked to the above, automation and data feed into the ability of firms to maximise their flexibility by producing in smaller batches: this is often referred to as mass customisation. Amongst many of the changes, Siemens (2015) notes the 'integration of value chains with seamless engineering' and a combination of cloud technology and data analytics. Bosch (2017) emphasises that technology is able to globally connect factories across the value chain to design and produce customised products, with flexible processes relying on versatile connected machinery complementing humans, short modification cycles and no rejects or inventory.

In a nutshell, the real game changer is argued to be digital technology that applied across the board is expected to change products and processes as well as to reorganise supply chains (Baur and Wee, 2015; Schmidt et al., 2015; Germany Federal Ministry of Education and Research, 2015). Thus, almost everything becomes 'smart' if digitally connected or enabled. The tight link between digital technology and *Industrie 4.0* has been also unpacked by countless reports by business service consultancies, such as KPMG (2016, 2017), BCG (2018), PwC (2016), McKinsey (2015) and Berger (2014), which have each offered

their interpretations, visions of the future and adoption in specific sectors and countries.

In summary, there is a growing debate on what a smart factory and a connected factory will look like once all the relevant technologies have been deployed. These new cyber-physical spaces will transform the flow and use of inputs in the factory, but more fundamentally will transform the whole supply chain across upstream and downstream suppliers. In this regard, the Internet of Things, robotics, sensing, space technology and mobile technology enabling machine-to-machine communications will allow the coordination of complex production operations via a seamless integration of functions residing not necessary in the same locale.

1.6 A more disruptive Industry 4.0+

However, the impact that the FIR should and could have is much more disruptive than designing a ‘lights out factory’. In the MAKERS project, researchers have worked on a broader definition of Industry 4.0+, arguing that the deployment of all the technologies of the FIR will trigger a transformational shift in the techno-socio-economic paradigm attuned to a green economy and society. Only a holistic definition of Industry 4.0+ can deliver opportunities for inclusive socio-economic growth (see Figure 1.2).

Figure 1.2 Industry 4.0+.

Source: Authors' elaboration.

Here it is argued that the disruptive and transformative changes of Industry 4.0+ can be clustered into five areas.

1.6.1 *New markets*

Looking at the broad spectrum of the technologies linked to the FIR, new markets will be created by firms, governments and consumers; these new markets will capture new consumption needs as well as pushing new technology-driven offers. Crucially, what will be new about these are the channels connecting production with consumers, users and accessers; indeed, the integration of digital technologies in products will change the channels through which people can buy, use, access or stream goods and services. Such new channels will branch out in a multitude of new modes of consuming, using or accessing depending on the product or service. The functionality and operability of these new markets – channels and modes – will depend on the producers' ability to activate and accustom consumers to them. There are concerns about digital divides resulting in actual digital exclusion as against empowerment.

1.6.2 *New products*

These new technologies will result in radically new products (goods and services). The way in which the latter are (and will be) 'digitally enabled or connected' will alter the way in which products are actually accessed, used or consumed, what needs they satisfy and what new uses they create. Examples of this are automotive and other forms of transport, mechanical engineering equipment and manufacturing in a broader sense (see below). Fundamental changes in biology, chemistry, medicine and pharmaceuticals will create new diagnostics and new treatments as well as new ways of administering them; such changes will feed into the food chain and bio-based industries. A drastic shift away from a fossil fuel economy and towards a bio-based economy will open up opportunities for completely new products that will have advanced functionalities, but crucially sustainable life cycle expectations.

1.6.3 *Product service innovation*

Product service innovation (Bustinza et al., 2017; Dimache and Roche, 2013) refers to the current debate on how manufacturing is moving from a product-based business model to a service-based business. This is the so-called servitisation of manufacturing (ibid) and suggests a cross-fertilisation of service practices and strategies to manufacturing in order to create a product-service system. It pushes consumers to overcome the need to own products, but rather to hire or lease them; in other words, the relationship between producer and consumer does not end with the sale, but is extended and weaved into a long-term relationship where the product is substituted by a use-oriented service or a result-oriented service (Baines et al., 2017).

1.6.4 New business models

Drawing on the above, to deliver in new markets, new products and a new product-service continuum, firms will be required to explore new business models. Digital technologies will offer a suite of opportunities – some of which are already entering current everyday life – in relation to both business-to-consumer and business-to business markets. Considering the subjects covered in Sections 1.6.1–1.6.3 above, firms will need to experiment in a business environment where increasingly firms face an innovation-production-consumption continuum. Co-innovation with consumers in the design of products can in extreme cases lead to unique, personalised offers that then materialise or become available (production); co-innovation in the delivery can also reflect elements of servitisation whereby the relationship between firm and customer is extended and renewed in the long term.

1.6.5 New customer-centred innovation

Cloud technology, big data and data analytics are a few of the technologies that will allow the design, manufacturing and delivery of personalised products (goods and services) thanks to a two-way flow of information and data between producers and customers. Equally, for instance, 3D printing will allow production at the point of consumption, reducing time lags, disruption, storage, stockpiling and so on. In summary, technology will deliver customer-centred continuous and incremental innovation.

1.7 Disrupting value creation and the organisation of production

The disrupting impact of Industry 4.0+ is likely to have manifold ramifications. On one level, new technologies will change the organisation of production between firms, whether they are co-located in the same region or territory in local systems of production or are linked by globally stretched supply chains. Technological change is expected to disrupt the spatial organisation of production depending on whether firms and systems are able to adapt and shift onto a new trajectory of change. On another level, the adoption and application of new technologies will also disrupt the parameters and the processes of value creation for firms, leading to a radical rethink of value creation along the supply chain in the past described by the ‘smile curve’ (Mudambi, 2008).

From a business economics perspective, it has been argued that firms can achieve a sustained competitive advantage by creating value from innovation but also by capturing this value (i.e. profiting) in markets and to a greater extent than their rivals (see Bailey et al., 2018, 2019). While originally developed in the context of business strategy, the idea that nations and regions should also be interested in capturing – in a sustainable way – a part of the value they help

create and/or co-create with other entities is also gaining recognition in the literature (*ibid*).

Recent developments in place-based strategy represent moves in the right direction since they recognise both value creation and value capture, but unfortunately largely ignore the distribution of value capture and hence the sustainability of the value-creation process. To fill this gap, Bailey et al. (2019) have advocated place-based strategies that cross-fertilise industrial with business strategy, proposing positioning and value capture through building bottleneck assets with the aim of fostering sustainable value creation and the capturing of co-created value. The scale and speed of the challenge posed by the FIR (De Propriis/WEF, 2016) also bring into sharp relief the need for new policy approaches to capture value at the regional and national levels as completely new value chains emerge (see Bailey et al., 2018). Taking the example of the auto industry, Bailey et al. (2018) suggest that the changes involved in Industry 4.0 and the shift to autonomous, connected and electric cars will require firms to position themselves in a completely new personal mobility ecosystem, offering opportunities for supply chain firms to reposition as this new value chain develops. This is beyond traditional ‘intersectoral’ upgrading as such, but rather is upgrading linked to the creation of a new value chain, which they term ‘new value chain upgrading’. Some of the regional industrial policy implications of these issues are explored by Bailey and De Propriis in the final chapter of this volume.

Value creation will also come from firms engaging with customers via new business models that will disrupt market relationships by locking consumers or users into a long-term relationship with firms as products are transformed into services. This is discussed by Vendrell-Herrero and Bustinza in Chapter 2. Servitisation is a new strategy that bundles services and products together and allows products to be uniquely personalised and to delegate the running and maintenance of the product to the firms. Indeed, servitisation not only provides a means for product differentiation, but also locks customers into a long-term relationship with the firm during the entire use life cycle. Servitisation is therefore seen as an opportunity to boost value creation and thereby the competitive advantage of European manufacturing firms. To date, however, no cross-country comparison has been attempted to establish the extent to which European firms have adopted servitisation strategies. Drawing on the ORBIS database (BvD), a map of servitisation activities across the EU-28 is presented. The method has recently been described in the literature and consists of observing the percentage of manufacturing firms that have a secondary North American Industry Classification System (NAICS) classification in knowledge-based services. The main findings report a weak but positive bivariate correlation between servitisation and both manufacturing value added as percentages of GDP (World Bank) and value in the Digital Economy and Society Index (Eurostat). Additionally, manufacturing and the development of digital capabilities are found to be substitutes and not to co-locate, implying that access to digital competences matters, but that firms need to strategically decide to pursue it.

Value creation also hinges on the innovativeness and ingenuity of people. However, the nature and the pervasiveness of this wave of new technologies will alter the balance between labour and capital, as well as change the skills, abilities and competences required in the workplace. This is explored by Pittarello, Trevisanato and De Propriis in Chapter 3, using job vacancies data for the UK, Germany and Italy. Overall, the pace and breadth of the adjustments that firms are required to make will shape their ability to leverage new technologies (Pittarello, Trevisanato and De Propriis, 2019).

1.8 Systemic disruptions and trajectories of change

The overwhelming narrative on automation, robotics, digitalisation and related technologies, in particular their application to the organisation of production within the firm and especially in *factories*, underplays the fact that firms do not operate in isolation regardless of their size, but rather are nodes in spatial and sectoral systems. Firms are key actors in deciding on innovation, capital and intangible investment, labour and skills, the location of production, the organisation of production and so on. However, they take decisions and function subject to the environment that surrounds them. Small and medium-sized firms in particular are embedded in local production systems that are enmeshed in regional economies that can be either specialised or diversified, with some presenting a significant service sector (Corò et al., 2017; Chaminade et al., 2017; Bellandi et al., 2017), especially in terms of services (OECD, 2010).

However, we would argue that technological change cannot deliver inclusive social and economic growth, as advocated in the Industry 4.0+ model, unless we understand its disrupting impact at the systemic level. In particular, we focus on two intersecting systems: the local system of production with micro-, small and medium-sized firms, and the global system of production coordinated by multi-national firms. We look at these in turn.

The extensive debate on drivers of regional economies and in particular on the local systems of production that can shape the growth or demise of regions left a grounded understanding of why and how regional industries emerge, grow and at times decline (Bellandi, De Propriis and Santini, 2019a; Isaksen and Trippel, 2014; Capello and Nijkamp, 2010). However, such debate has evolved in a context where firms were operating within a stable and known technological paradigm. The innovation capacity of firms was tightly linked to the systemic knowledge and know-how they could assess and leverage through dense socio-economic exchanges connecting the local productive fabric. Learning and innovation processes differ across such systems depending on the nature of the innovation infrastructure therein. The innovation literature distinguished between science and technology-based (STI) and learning-by-doing, by-using and by-interacting (DUI) innovation modes (Lundvall, 2016); the former characterises innovation processes, for instance, in university-centred clusters in the US (Becattini et al., 2009), such as in ICT, and in regional innovation systems, such as the Cambridge biotech cluster (Cooke, 2002). The STI

innovation mode has been used to explain processes of incremental innovation in sectors which are more high tech and where innovation has tended to be science-pushed and underpinned by codified knowledge. On the other hand, local production systems in relatively mid- or low-tech industries have been argued to innovate via a DUI learning mode, whereby learning and innovation is argued to occur via the sharing, exchange and transmission of often tacit knowledge eased by co-location as well as strong socio-cultural ties (Dei Ottati, 2009). The vast literature on Marshallian industrial districts has expanded on the latter and has introduced the concept of decentralised innovation creativity to capture the fact that innovation relies on ‘the decentralization of the sources of new knowledge’ (Bellandi, 1996: 354).

The current technological shift poses some clear challenges to local systems of production of small and medium-sized firms, especially those relying on a DUI learning mode. The key questions here are: how will the system access new technologies? How will technological change the systemic knowledge base? Which actors will drive or hinder the necessary transformative process of adaptation? This volume includes five contributions that unpack such issues with novel conceptual propositions and enlightening case study analysis.

In the first, Bellandi, Chaminade and Plechero (in Chapter 4) introduce a novel conceptual framework for understanding how different knowledge bases (analytic, synthetic and symbolic) can be accessed and combined at different territorial scales, looking at which mechanisms can be used to favour positive transformation paths in local productive systems. They apply such framework to the role of combinatorial knowledge for sustainable transformation under the impact of global challenges, such as those posed by Industry 4.0+. Case studies in Italy and Sweden illustrate the multi-scalarity of knowledge bases combined in different paths of industrial transformation addressing the challenge of technological change.

Next, in Chapter 5, Bellandi, Santini, Veccioli and De Propriis challenge dominant approaches to Industry 4.0 that effectively favour large firms in the application of new digital technologies, leaving local productive systems (LPSs) of small firms with the gloomy prospect of either declining or becoming dependent on large technological companies. Instead, in a broader approach, such as the one developed by the MAKERS project, Industry 4.0+ contemplates the possibility for such LPSs to integrate new technologies into existing socio-economic systems, allowing them to thrive; this would be the case for so-called ‘Mark 3 industrial districts’. Here, appropriate solutions combine new digital-based technologies in processes of production and products, and possibly other innovations, with a renewed integration with artisan and creative capabilities. Such solutions require not just adaptations internal to single firms, but more crucially a collective rerouting that involves the recombination of productive knowledge at the system level.

Following on from this, Ramirez in Chapter 6 analyses initial efforts to motivate a regional transition towards a sustainable and innovative forest-based bio-economy in the Värmland Region of Sweden. The chapter discusses the

notion of a bio-economy socio-technical system based on the development of renewable biological resources and its implications for local manufacturing systems. The account highlights the importance of place-specific dynamics of transition processes, such as the existence of a local natural resource with the potential to become a new source of raw materials, new regional visions and policies, and the role of local formal and informal institutions in the process of transition towards new regional environmentally sustainable 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 in processes of regional diversification. The multi-scalar nature of the change is also analysed.

The next regional study comes from Coro and Volpe (in Chapter 7), who provide an analysis of firms' adoption of the latest digital technologies in the Veneto region, one of the main manufacturing areas in Italy. The chapter focuses on factors that enable firms to adopt technologies related to Industry 4.0, with special attention being paid three main aspects: human capital, international openness and financial structure. The empirical analysis is based on a sample of firms that operate in the manufacturing, construction and business services. They unearth a heterogeneous use of Industry 4.0 technologies across different industries, allowing for the identification of distinct technology frontiers between sectors. The findings also reveal a positive relationship between the adoption of digital technologies and openness to international markets, as well as with highly skilled and highly educated human capital. Indeed, digital users show greater productivity than other firms. However, financial performance is less clear. In fact, firms that adopt new digital technologies have a more balanced financial structure, but they do not show higher profitability ratios than non-users. This result depends on a longer-run return on investment and on a different labour and capital ratio inside the firm.

Finally in this section, Fassio and Nathan in Chapter 8 look at the evolution of Industry 4.0 producers in Sweden during the 2000s and early 2010s. Like many industries before it, manufacturing is being reshaped by new technology. Much existing analysis on the FIR or 'Industry 4.0' has focused on users and, more broadly, on awareness and levels of readiness in existing businesses. Using MONA microdata, the analysis reveals smart manufacturing clusters in Stockholm and other Swedish cities with distinctive ecosystem features.

1.9 A new local-global continuum

The hyper-globalisation (Friedman, 2005) that was witnessed in the 1990s and early 2000s appears to be over; we are seeing signs of an emerging debate that is acknowledging fundamental change in the attitudes towards and the strategies related to globalisation. From a blind and unchallenging infatuation with globalisation in all its forms, including the globalisation of markets and production, culture and tastes, a deep untrustworthiness towards it emerged following the 2008 financial crisis. Indeed, society first started questioning,

doubting and rejecting the claims that globalisation was not only inevitable but also had to be encouraged in order to allow markets to work efficiently, benefiting consumers and creating wealth (McGrew, 1998). The globalisation of production in particular led to the offshoring of labour-intensive manufacturing functions from advanced economies to low-income economies driven by the creation of multi-national enterprises' global value chains. The disappearance of entire industries in some regions of Europe and the US created large masses of unemployed or under-employed communities (Bell and Blanchflower, 2018) whose livelihood and sense of identity remained depressed for decades due to a lack of job alternatives. These communities expanded as a consequence of the 2008 financial crisis, shedding light to the real 'losers' in advanced economies of 'globalisation 3.0' as discussed by Baldwin (2019).

The recent debate on de-globalisation is discussed in Pegoraro, De Propriis and Chidlow in Chapter 9, where they also present compelling evidence that the economic activities of firms show signs of *de-globalising*. A new appreciation of the value of manufacturing activities in light of the current geopolitical turmoil in terms of jobs and inclusive growth, as well as the emergence of new technologies with all their implications (*The Economist*, 2009), are creating a new continuum linking local places with global spaces. Understanding emerging de-globalisation forces matters since changes in technological paradigms and in the nature of markets can significantly impact on firms' location decisions in relation to manufacturing activities (Mudambi et al., 2018; Li and Bathelt, 2018; Chidlow et al., 2015; Chidlow et al., 2009). More specifically, such location decisions can relate to the adaptation of a reshoring strategy, which involves bringing back the manufacturing activity (or part of it) from a foreign market to a home market.

This latter development is explored by Kinkel, Pegoraro and Coates in Chapter 10, who compare reshoring trends across the EU and the US by focusing on three selected European regions, namely Veneto in Italy, Baden-Württemberg in Germany and the West Midlands in the UK. They explore whether a reshoring strategy is a viable solution for sustainable competitiveness or not, and evidence on reshoring in the US, with three criteria highlighted to be considered in adopting a reshoring strategy. The direct link between reshoring and technological change is unpacked further by Kinkel in Chapter 11 as he 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 Industry 4.0 technologies may affect global value chains in two ways: firstly, the increased productivity provided by Industry 4.0 production technologies may neutralise the cost-factor advantages of offshoring locations and make labour arbitrage less appealing; and, secondly, increased flexibility provided by Industry 4.0 technologies may provide an incentive for firms to locate production close to their European customers and regain some of the responsiveness lost in fine-sliced 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.

In Chapter 12, Mafini offers an interesting insider's perspective on the EU policy agenda for Industry 4.0 and discusses the underlying rationales of policies. For these purposes, the chapter builds upon recent major communications and documents of the European Commission, as well as key initiatives and platforms launched to support the transition of European industries and territories towards the fourth industrial era. In doing so, it puts forward an integrated background and a multi-dimensional policy approach of EU frameworks, including, for instance, 'Industrial Renaissance, Industrial Modernisation and Key Enabling Technologies' (KETs) and the 'Digitizing European Industry initiative' – dedicated to stimulating, accelerating and monitoring Industry 4.0. Finally, the uptake of Industry 4.0 in the research and innovation strategies smart specialisation strategy is examined, relying initially on information from the European Commission's Eye@RIS3 platform.

Following this perspective on EU policies, in the final chapter of the volume, Bailey and De Propriis reflect on the extent to which technological change – including AI – inherent in the FIR will require further adjustments to EU regional and cohesion policies in order to allow the latter to have a 'transformative' power. In so doing, Chapter 13 considers the evolution of EU policies in terms of vision, objectives and instruments since the 1990s. Priorities have changed over time, but, the authors argue, have always been underpinned by a concern for inter-regional socio-economic cohesion. The disruptions brought about by FIR technologies have the potential to introduce new layers of socio-economic divides. The chapter discusses whether and how new technologies will widen economic divergence between low- and high-performing regions and states or, alternatively, whether and how they might allow some regions to 'leap-frog' with a consequent faster catching up. The chapter concludes with a 'call to arms' for a transformative regional industrial policy given the scale of change coming.

References

- Amison, P. and Bailey, D. (2014). Phoenix industries and open innovation? The Midlands advanced automotive manufacturing and engineering industry. *Cambridge Journal of Regions, Economy and Society*, 7(3): 397–411.
- Asheim B., Boschma R. and Cooke, P. (2011). Constructing regional advantage: platform policies based on related variety and differentiated knowledge bases. *Regional Studies*, 45(7): 893–904.
- Bailey, D. (2016) Follow that (driverless) cab! *Birmingham Post*. Available at: www.birminghampost.co.uk/business/business-opinion/follow-that-driverless-cab-11817752.

- Bailey, D. (2017) Electric vehicle market sparks into life as ICE age comes to end? *Birmingham Post*. Available at: www.birminghampost.co.uk/business/business-opinion/electric-vehicle-market-sparks-life-13354818.
- Bailey, D. and De Propriis, L. (2014) Manufacturing reshoring and its limits: the UK automotive case. *Cambridge Journal of Regions, Economy and Society*, 7(3): 379–398.
- Bailey, D., Pejic, D. and Pegoraro, D. (2018) Case studies of EU value chain upgrading. MAKERS Paper, D5.2. MAKERS/European Commission. Available at: www.makers-rise.org/wp-content/uploads/2018/02/D5.2-Paper-on-a-case-study-of-value-chain-upgrading-protected.pdf.
- Bailey, D., Pitelis, C. and Tomlinson, P. (2018) A place-based developmental regional industrial strategy and/or sustainable capture of co-created value. *Cambridge Journal of Economics*, 42(6): 1521–1542.
- Bailey, D., Pitelis, C. and Tomlinson, P. (2019) Strategic management and regional industrial strategy: cross-fertilisation to mutual advantage. *Regional Studies*.
- Baines, T., A Z Bigdeli, O F Bustinza, V Guang Shi, J Baldwin, and K Ridgway (2017) Servitization: revisiting the state-of-the-art and research priorities. *International Journal of Operations & Production Management*, 37(2): 256–278.
- Baldwin, R. (2019) *The Globotics Upheaval: Globalisation, Robotics and the Future of Work*. New York, Oxford University Press.
- Barca, F. (2011) Alternative approaches to development policy: intersections and divergences. In OECD, *OECD Regional Outlook 2011*. OECD Publishing, pp. 215–225.
- Barca, F., McCann, P. and Rodríguez, P. (2012) The case for regional development intervention: place-based versus place-neutral approaches. *Journal of Regional Science*, 52(1): 134–152.
- Baur, C. and Wee, D. (2015) Manufacturing’s next act. McKinsey and Company, Available at: www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act.
- BCG (2018) Embracing Industry 4.0 – and rediscovering growth. Available at: www.bcg.com/capabilities/operations/embracing-industry-4.0-rediscovering-growth.aspx.
- Bell, D.N. and Blanchflower, D.G. (2018). Underemployment in the US and Europe (No. w24927). National Bureau of Economic Research.
- Becattini, G., Bellandi, M. and De Propriis, L. (eds.) (2009). *A Handbook of Industrial Districts*. Cheltenham: Edward Elgar.
- Bellandi, M. (1996) Innovation and change in the Marshallian industrial District. *European Planning Studies*, 4(3): 357–368. DOI: <https://doi.org/10.1080/09654319608720351>.
- Bellandi, M. and De Propriis, L. (2017). New forms of industrial districts. *Economia e Politica Industriale*, 44(4): 411–427.
- Bellandi, M., De Propriis, L. and Santini, E. (2019a) Endogenous rerouting and longevity in systemic organisations of production. In F. Hervás and J.-L. Belussi (eds), *Agglomeration and Firm Performance*. Springer, pp. 207–222.
- Bellandi, M., De Propriis, L. and Santini, E. (2019b). An evolutionary analysis of industrial districts: the changing multiplicity of production know-how nuclei. *Cambridge Journal of Economics*, 43(1): 187–204.
- Bellandi, M. and Santini, E. (2018) Territorial servitization and new local productive configurations: the case of the textile industrial district of Prato. *Regional Studies*, 53: 356–365.

- Bellandi, M. et al. (2017) Deliverable D3.1. Available at: www.makers-rise.org/wp-content/uploads/2018/03/D3.1-Paper-on-the-impact-of-new-technology-on-the-organisation-of-production-in-high-tech-districts-or-clusters.-Protected.pdf.
- Bellandi, M., Santini, E., De Propriis, L. and Veccioli, C. (2018) *A Place-Based View on Industry 4.0 in Systems of SMEs*. Mimeo.
- Berger (2014) Industry 4.0: the new Industrial Revolution – how Europe will succeed. Roland Berger Strategic Consultants.
- Berkeley, N., Bailey, D., Jones, A. and Jarvis, D. (2017) Assessing the transition towards battery electric vehicles: a multi-level perspective on drivers of, and barriers to, take up. *Transportation Research Part A: Policy and Practice*, 106: 320–332.
- BNEF (Bloomberg New Energy Finance) (2016) Electric vehicles to be 35% of global new car sales by 2040. Available at: <https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040>.
- BNEF (Bloomberg New Energy Finance) (2017) Electric cars to reach price parity by 2025. Available at: <https://about.bnef.com/blog/electric-cars-reach-price-parity-2025>.
- Bosch (2017) Intelligent systems for the flexible factory 4.0. Available at: www.bosch.com/explore-and-experience/industry-4-0-flexible-production-line.
- Brynjolfsson, E. and McAfee, A. (2014) The second machine age: work, progress, and prosperity in a time of brilliant technologies. W.W. Norton.
- Bustinza O.F., Vendrell-Herrero, F., Santini, E., Bellandi, M. and De Propriis, L. (2017) Servitization on manufacturing. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/02/Deliverable-1.2-protected.pdf.
- Capello, R. and Nijkamp, P. (eds.). (2010). *Handbook of Regional Growth and Development Theories*. Edward Elgar.
- Chaminade, C., Bellandi, M., Plechero, M. and Santini, E. (2017) A paper on the role of RIS and NIS on manufacturing upgrading, including a case study analysis on the role of knowledge transfer to upgrade the textile industry in Europe. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/03/D2.2-A-paper-on-the-role-of-RIS-and-NIS-on-manufacturing-upgrading.pdf.
- Chidlow, A., Holmström-Lind, C., Holm, U. and Tallman, S. (2015) Do I stay or do I go? Sub-national drivers for post-entry subsidiary development. *International Business Review*, 24(2): 266–274.
- Chidlow, A., Salciuvienė, L., and Young, S. (2009) Regional determinants of inward FDI distribution in Poland. *International Business Review*, 18(2): 119–133.
- Cooke, P. (2002) Regional innovation systems: general findings and some new evidence from biotechnology clusters. *Journal of Technology Transfer*, 27(1): 133–145.
- Corò, G., Volpe, M., Pejčić, D. and De Propriis, L. (2017) Paper on technological upgrading in manufacturing in the light of the new manufacturing model, MAKERS Paper, D1.1. MAKERS/European Commission. Available at: www.makers-rise.org/wp-content/uploads/2017/10/D1.1-Manufacturing-4.0-protected.pdf.
- Cowen, T. (2013) *Average Is Over*. Dutton.
- De Propriis, L., Ramirez, P., Robinson, P., Bailey, D. and Pegoraro, D. (2017) EU positioning in key manufacturing GVCs. MAKERS Paper, D5.1. MAKERS/European Commission. Available at: www.makers-rise.org/wp-content/uploads/2017/10/D5.1-Global-value-chains-protected.pdf.

- De Propriis, L./WEF (World Economic Forum) (2016) How the Fourth Industrial Revolution is powering the rise of smart manufacturing. Available at: www.weforum.org/agenda/2016/06/how-the-fourth-industrial-revolution-is-powering-the-rise-of-smart-manufacturing.
- Dei Ottati, G. (2009) Semi-automatic and deliberate actions in the evolution of industrial districts, in G. Becattini, M. Bellandi and L. De Propriis (eds), *A Handbook of Industrial Districts*. Edward Elgar, pp. 204–215.
- Deloitte (2015) Industry 4.0: challenges and solutions for the digital transformation and use of exponential technologies. Available at: www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf.
- Deutsche Bank (2014) Industry 4.0: upgrading of Germany's industrial capabilities on the horizon. Available at: www.dbresearch.com/PROD/RPS_EN-PROD/PROD000000000451959/Industry_4_0%3A_Upgrading_of_Germany%E2%80%99s_industrial_ca.pdf.
- Dimache, A. and Roche, T. (2013). A decision methodology to support servitisation of manufacturing. *International Journal of Operations and Production Management*, 33(11–12), 1435–1457.
- The Economist* (2009) International: turning their backs on the world. 19 February.
- EU Parliament (2015) Industry 4.0: digitalisation for productivity and growth. Briefing.
- European Commission (2014) *Communication: Towards an Industrial Renaissance. COM/2014/014 Final*. Brussels: European Commission.
- European Commission (2016) Industry 4.0. Brussels: European Commission.
- Friedman, T.L. (2005). *The World is Flat: A Brief History of the Globalised World in the 21st Century*. Allen Lane/Penguin.
- Germany Federal Ministry of Education and Research (2015) Platform Industrie 4.0. Available at: www.plattform-i40.de/PI40/Navigation/EN/Home/home.
- Gowling, W.L.G. (2016) Are you data driven? UK Autodrive White Paper. Available at: https://landing.gowlingwlg.com/driverless/?utm_source=driverless-vehicles-regulating-moral-programming-in-order-to-move-forward&utm_medium=gowlingwlg-website&utm_campaign=autodrive#download.
- GTAI (2014) *Industrie 4.0: Smart Manufacturing for the Future*. German Trade and Invest.
- Heng, S. (2014) Industry 4.0: upgrading of Germany's industrial capabilities on the horizon. Available at: <https://ssrn.com/abstract=2656608>.
- Hildreth, P. and Bailey, D. (2013) The economics behind the move to 'localism' in England. *Cambridge Journal of Regions, Economy and Society*, 6(2): 233–249.
- Isaacson, W. (2014) *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*. Simon & Schuster.
- Isaksen, A. and Tripl, M. (2014) Regional industrial path development in different regional innovation systems: a conceptual analysis (No. 2014/17). Lund University, CIRCLE-Center for Innovation, Research and Competences in the Learning Economy.
- Kinkel, S., Dewanti, R.T., Zimmermann, P. and Coates, R. (2017) *Measuring Teshoring Trends in the EU and the US*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/02/D4.1-Measuring-reshoring-trends-in-the-EU-protected.pdf.

- Kondratieff, N.D. (1979). The long waves in economic life. *Review* (Fernand Braudel Center), II(4): 519–562.
- Kondratieff, N.D. and Stolper, W.F. (1935) The long waves in economic life. *Review of Economics and Statistics*, 17(6): 105–115.
- KPMG (2016) The factory of the future. Industry 4.0 –The challenges of tomorrow. Available at: <https://assets.kpmg/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf>.
- KPMG (2017) Beyond the hype: separating ambition from reality in Industry 4.0. Available at: <https://home.kpmg/xx/en/home/insights/2017/05/beyond-the-hype-separating-ambition-from-reality.html>.
- KPMG/SMMT (2015) Connected and autonomous vehicles – the UK economic opportunity. Available at: <https://home.kpmg.com/content/dam/kpmg/pdf/2015/04/connected-and-autonomous-vehicles.pdf>.
- KPMG/SMMT (2016) *The Digitalisation of the UK Automotive Industry*. Available at: www.smmt.co.uk/wp-content/uploads/sites/2/smmt_the-digitalisation-of-the-uk-auto-industry_kpmg-apr-2017.pdf.
- Li, P. and Bathelt, H. (2018) Location strategy in cluster networks. *Journal of International Business Studies*, 49(8): 967–989.
- Lundvall, B.Å. (2016) Innovation as an interactive process: from user–producer interaction to the national systems of innovation. In B.Å. Lundvall (ed.), *The Learning Economy and the Economics of Hope*. Anthem Press, pp. 61–84.
- Marsh, P. (2013) *The New Industrial Revolution: Consumers, Globalization and the End of Mass Production*. Yale University Press.
- Marsh, P. (2015) *New Manufacturing: Opportunities and Policies: How Ideas in Production Industry Can Re-energise the World Economy*. Report for the OECD Centre on Entrepreneurship, SMEs and Local Development.
- Marshall, A. (1923) *Industry and Trade*, 4th edn. Macmillan.
- McCann, P. and Ortega-Argilés, R. (2015) Smart specialization, regional growth and applications to European Union cohesion policy. *Regional Studies*, 49(8): 1291–1302.
- McGrew, A.G. (1998) The globalisation debate: putting the advanced capitalist state in its place. *Global Society*, 12(3): 299–321.
- McKinsey (2015) Manufacturing’s next act. Available at: www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act.
- McKinsey (2016) Disruptive trends that will transform the auto industry. Available at: www.mckinsey.com/industries/high-tech/our-insights/disruptive-trends-that-will-transform-the-auto-industry?cid=other-eml-ttn-mip-mck-oth-1612.
- McKinsey Global Institute (2012) *Manufacturing of the Future: The Next Era of Global Growth and Innovation*. McKinsey.
- Mudambi, R. (2008) Location, control and innovation in knowledge intensive industries. *Journal of Economic Geography*, 8(5): 699–725.
- Mudambi, R., Li, L., Ma, X., Makino, S., Qian, G. and Boschma, R. (2018) Zoom in, zoom out: geographic scale and multinational activity. *Journal of International Business*, 49(8), 929–941.
- Muller, P., Devnani, S., Julius, J., Gagliardi, D. and Marzocchi, C. (2016). *Annual Report on European SMEs 2015/2016 – SME Recovery Continues*. Contract number: EASME/ COSME/2015/012. European Union.
- OECD (2010) *SMEs, Entrepreneurship and Innovation*. OECD Publishing.

- OECD (2015) *ICTs and Jobs: Complements or Substitutes? The Effects of ICT Investment on Labour Market Demand by Skills and by Industry in Selected Countries*. OECD Digital Economy Working Papers, No. 259. OECD Publishing.
- OECD (2016) *Science, Technology and Innovation Outlook 2016: Megatrends Affecting Science, Technology and Innovation*. OECD Publishing.
- OECD (2017a) *Small, Medium, Strong: Trends in SME Performance and Business Conditions*. OECD Publishing.
- OECD (2017b) *The Next Production Revolution: Implications for Governments and Business*. OECD Publishing.
- Pegoraro, D., De Propriis, L. and Bailey, D. (2017) *Paper on Reshoring Trends and Drivers of Shorter Value Chains*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2017/10/D4.2-Reshoring-protected.pdf.
- Pejčić, D., Bailey, D. and Pegoraro, D. (2018) *Paper on a Case Study of Value Chain Upgrading*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/02/D5.2-Paper-on-a-case-study-of-value-chain-upgrading-protected.pdf.
- Perez, C. (2010) Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, 34(1): 185–202.
- Pittarello, A., Trevisanato, A. and De Propriis, L. (2019) *Report on the Employment Transformation in EU Manufacturing Sectors*. MAKERS Report to the EU Commission. Available at: www.makers-rise.org/wp-content/uploads/2019/05/Skills-report_final.pdf.
- PwC (2016) *Industry 4.0: Building the Digital Enterprise*. Available at: www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.
- Ramirez, P. and Ciappei, S. (2018) *Paper on the Impact of GINs on Manufacturing Upgrading*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/03/D2.1-Paper-on-the-impact-of-GINs-on-manufacturing-upgrading.pdf.
- Rifkin, J. (2011) *The Third Industrial Revolution*. Palgrave Macmillan.
- Rifkin, J. (2013) *The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World*. Palgrave Macmillan.
- Rifkin, J. (2014) *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism*. Palgrave Macmillan.
- Rodrik, D. (2004) *Industrial Policy for the 21st Century*. Cambridge, MA: John F. Kennedy School of Government.
- Rodrik, D. (2008) *One Economics, Many Recipes: Globalization, Institutions, and Economic Growth*. Princeton University Press.
- Santini, E. and Bellandi, M. (2017) *Paper on the Impact of New Technology on the Organisation of Production in High-tech Districts or Clusters*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/03/D3.1-Paper-on-the-impact-of-new-technology-on-the-organisation-of-production-in-high-tech-districts-or-clusters-Protected.pdf.
- Schmidt, R., Möhring, M., Härtling, R., Reichstein, C., Neumaier, P. and Jozinović, P. (2015) Industry 4.0: potentials for creating smart products: empirical research results. Conference Proceedings. International Conference on Business Information Systems.
- Schumpeter, J.A. (1942) *Capitalism, Socialism and Democracy*. New York: Harper.
- Schwab, K. (2016) *The Fourth Industrial Revolution*. Geneva: World Economic Forum.

- Simoudis, E. (2015) The innovation-driven disruption of the automotive value chain (part 1). Synapse Partners. Available at: <http://synapsepartners.co/2015/04/06/the-innovation-driven-disruption-of-the-automotive-value-chain-part-1>.
- Simoudis, E. (2017) A new value chain for next-generation personal mobility. *Re-imagining Corporate Innovation with a Silicon Valley Perspective Blog*. Available at: <https://corporate-innovation.co/2017/04/25/a-new-value-chain-for-next-generation-mobility>.
- Volpe, M. and Coro', G. (2018) *Paper on Cluster Upgrading with Case Studies*. MAKERS Report. Available at: www.makers-rise.org/wp-content/uploads/2018/03/D3.2-Paper-on-cluster-upgrading-with-case-studies.-Protected.pdf.
- Walker, J. and Johnson, C. (2016) *Peak Car Ownership: The Market Opportunity of Electric Automated Mobility Services*. Rocky Mountain Institute. Available at: www.rmi.org/wp-content/uploads/2017/03/Mobility_PeakCarOwnership_Report2017.pdf.
- Wall Street Journal* (2002) Workers aren't included in lights-out factories. Available at: www.wsj.com/articles/SB1037666065632825628.
- World Bank (2017) *Trouble in the Making? The Future of Manufacturing-Led Development*. World Bank.