INDUSTRY 4.0 AND REGIONAL TRANSFORMATIONS

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Industry 4.0 and Regional Transformations

This edited volume brings together a group of expert contributors to explore the opportunities and the challenges that Industry 4.0 (smart manufacturing) is likely to pose for regions, firms and jobs in Europe. Drawing on theory and empirical cases, it considers emerging issues like servitization, new innovation models for local production systems and the increase in reshoring.

Industry 4.0 and Regional Transformations captures the complexity of this new manufacturing model in an accessible way and considers its implications for the future. It will be essential reading for advanced students and researchers and policy makers in regional studies, industrial policy, economic geography, innovation studies, operations management and engineering.

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Preface

MAKERS: the project. The people. The ideas

The MAKERS project was a multi-stakeholder platform funded under the Horizon 2020 MSCA-RISE programme that brought together business, academia and policy makers for three years from 2016 to 2019. Led by the Birmingham Business School (at the University of Birmingham, UK), its academic partners included Universita' di Venezia Ca' Foscari (Italy); Aston University (UK), the University of Granada (Spain); Fakultät für Informatik und Wirtschaftsinformatik Hochschule -Karlsruhe (Germany); Universite' de Neuchatel (Switzerland); the University of Lund (Sweden); and the National University Singapore (Singapore). Policy stakeholders included the Fondazione Recerca e Innovazione – Firenze (Italy); Unioncamere Veneto (Italy); the Centre for European Policy Studies, Brussels (Belgium); and VINNOVA, Sweden's Innovation Agency (Sweden). Finally, business stakeholders included BASIC, Paris (France); Galdon Software (Spain); Steinbeis Transferzentren GmbH (Germany); Rieke Packaging Systems (UK); and the Reshoring Institute, San Diego (US).

MAKERS' research agenda was way ahead of the game when we started. Our focus was on Smart Manufacturing or Manufacturing 4.0 with the objective of understanding how new technologies were going to impact on firms' business models, on the innovation capabilities of EU regions and on the dynamics and geography of global value chains. In particular at the beginning of the project, the main question was to what extent the wave of new technologies inherent in Industry 4.0 was going to cause a shock for sectors, regions, firms and markets, given the extent and the breadth of the disruption and of the change required. Examples of these include: shocks to firms where digital technology will replace more labour; shocks to supply chains where connected digital technology will allow real-time communications between physically distant machines without human intervention; shocks to existing sectors superseded by the rise of new sectors; and shocks to traditional learning and innovation processes as new technologies force discontinuities.

The overarching aim of MAKERS was to identify factors and pathways to enable regional economies to embrace such disruptive industrial transformations in view of sustaining their longer-term socio-economic growth and prosperity.

The unit of analysis of our research has been mainly the regional economy and locally embedded systems of production; this has allowed us to focus on the impact of technological change not just at the firm level, but more crucially at the systemic level, namely at the intersection between buyers–suppliers relationships and between knowledge flows between people and firms. The systemic and relational perspective of MAKERS' analysis meant that we were able to overcome the efficiency-based and firm-based arguments often associated with Industry 4.0, and to offer a broader and more holistic understanding of the impact of new technology on inter-firm relations, on systems and on the producer–consumer nexus. We have called this Industry 4.0+ to stress that new technologies have a wider transformative power on the nature of business and markets, on the dynamics of innovation and learning, and on the implementation of an ecological agenda.

MAKERS observed recent trends with many case studies from across the EU and the US, and a wealth of data. Evidence-based analysis informed policy considerations that are discussed in the final chapters of the volume.

This open access volume aims to be our contribution to a very lively and fast-moving debate, and we thank the partners for their contributions and enthusiasm throughout the project and the writing of this volume.

1 Disruptive Industry 4.0+

Key concepts

Lisa De Propris and David Bailey

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 agued 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 chances 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.

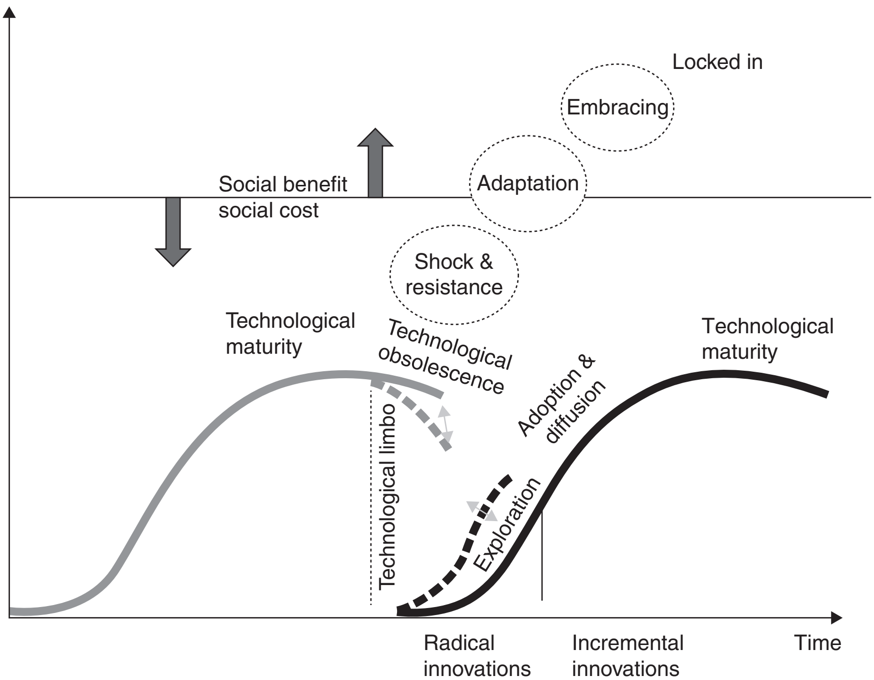

Figure 1.1 Technological change.
Source: Authors' adaptation from Perez (2010).

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, sensoring, 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 (Deusche 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, sensoring, 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).

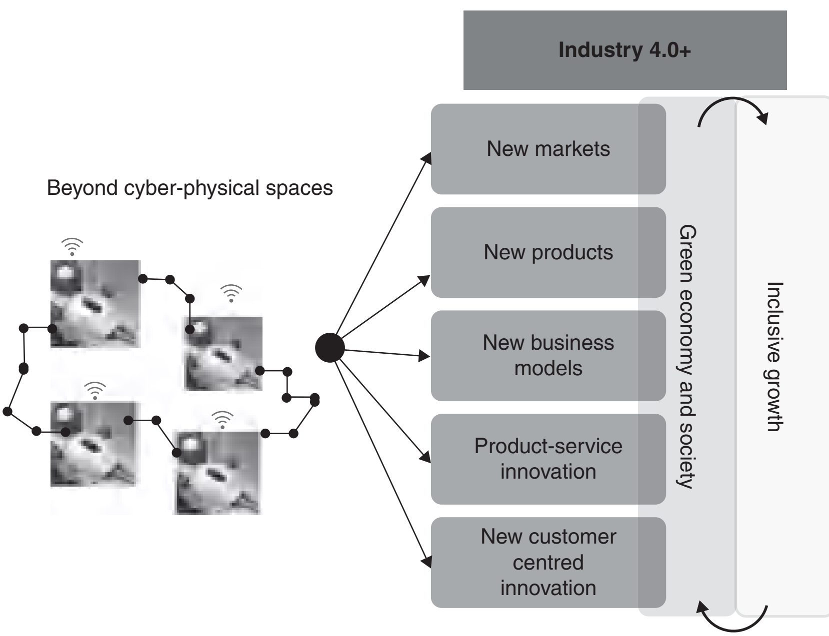

Figure 1.2 Industry 4.0+.
Source: Authors' elaboration.

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 Propris/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 Propris 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 Propris 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 Propris, 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 Propris and Santini, 2019a; Isaksen and Trippl, 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, Vecciolini and De Propris 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 Propris 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; Chidolow 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 Propris 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.

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2 Servitization in Europe

Ferran Vendrell-Herrero and Oscar F. Bustinza

2.1 Introduction: motivation, definitions and research objectives

As a result of a reduction in transport costs, a rise in offshoring of European and US production to developing economies in the 1990s changed the way the global economy was conceptualized during the twentieth century (Krugman and Venables, 1995). Countries like China, India, Turkey and Mexico benefited from production offshoring and other foreign direct investments from Western economies, significantly improving their manufacturing industry. Over the years, these countries have become increasingly competitive and could threaten the manufacturing leadership of Europe and the US as the latter functioned during the twentieth century (Baldwin, 2016).

Advanced economies are characterized by high wages, high skills and high disposable income. Business models that focus on the exploitation of economies of scale thus became obsolete for European manufacturers at the turn of the twenty-first century. With the rapid rise of Asia's global production, firms in advanced economies must increase customization while maintaining high levels of scalability and efficiency in order to develop and maintain a competitive advantage. New competitive conditions require a better understanding of what drivers and bottlenecks can enable manufacturing sectors to transition to more innovation-intensive and difficult-to-imitate business models. One way of sustaining the competitive advantage of these sectors in the medium and longer term is through bundling products and services and/or through digital upgrading of product features (Porter and Heppelman, 2014). This chapter endeavours to better understand and to quantify the use of these business models in Europe.

Product and service firms have conventionally been thought of as largely independent entities. Evidence suggests, however, that potential synergies between products and services could ultimately enhance consumer satisfaction. The business strategy of bundling products and services in manufacturing sectors is known as the *servitization* of manufacturing (Bustinza, Vendrell-Herrero and Baines, 2017). In servitization, production firms attempt to enhance product features and capabilities, as well as consumer satisfaction, and to increase product differentiation by including services that support product capabilities during the product's entire life cycle in their business portfolio. By incorporating services as an integral part of the product to be sold, firms gain more customizable offerings. The services provided are not homogeneous; they differ substantially in their levels of risk and competition, and their potential to create competitive advantages. Some manufacturers create wealth by offering a wide range of 'break-fix' services (e.g., maintenance), while others develop more sophisticated outcome-based contracts (Visnjic, Neely and Jovanovic, 2018). Successful examples of the latter include Rolls-Royce's TotalCare solution and Xerox's delivering 'pay-per-click' scanning, copying and printing of documents.

In Europe, the rise of servitization is evidence of a business environment that has significantly dented the weight of manufacturing's contribution to GDP. The European manufacturing industry has been in relative decline for the last 30 years and has recently reached an all-time minimum of 15% of total GDP, a share that the European Commission has been committed to raise to 20% as part of its 2020 Agenda (Veugelers, 2013). European initiatives have also been devoted to promoting servitization across manufacturing firms (Hojnik, 2016). Despite this growing interest, no research as yet grounds how to map the heterogeneities in servitization activity across Europe (Lafuente, Vaillant and Vendrell-Herrero, 2018).

One stream of research does, however, focus on the territorial aspect of servitization (Vendrell-Herrero and Wilson, 2017). This research underscores the importance of the Knowledge-Intensive Business Services (KIBS) sector (Horvath and Rabetino, 2018; Seclen-Luna and Barrutia-Güenaga, 2018) and provides some isolated pictures of servitization activity in Europe (Crozet and Millet, 2017; Gomes et al., 2018; Sforzi and Boix, 2018). This research stream focuses on secondary datasets and thus considers a large and broad set of representative firms. A summary of these methods is given in Table 2.1.

Crozet and Millet (2017) use data from the French fiscal authority to differentiate between sales from products and sales from services. These authors visualize that 70% of French manufacturers are servitized, but their method suffers from two limitations. Firstly, the sample can be neither extrapolated (data from different fiscal authorities might not be comparable) nor scalable (data are confidential; no repositories exist to merge data from various countries). Secondly, the data could over-represent servitization, as they account for all types of services (basic as well as advanced) and do not consider the option of bundling products and services.

The figures obtained by Gomes et al. (2018) and Sforzi and Boix (2018) are considerably more pessimistic, although their methods are scalable to all EU-28 countries and consider only knowledge-based (advanced) services. Both articles use ORBIS, a Bureau van Dijk (BvD) service that provides firms' balance sheet statements and covers a wide spectrum of countries. The method used by Sforzi and Boix (2018) focuses on searching keywords in the description of the business. By examining firms located in specifically industrial districts

Table 2.1 Measuring servitization using secondary sources

Method	*Source*	*Articles*	*Range*	*Advantages/limitations*
Identifies product firms with positive service sales	Compustat	Suarez, Cusumano and Kahl (2013)	42% (US)	Does not include firms selling bundles of products and services. Inflated by multi-sector firms. The method is rich for firm-level analysis but not scalable or extrapolable to other territories Intensive and extensive margins of servitization.
	Fiscal Authorities and Central Banks	Crozet and Millet (2017)	70% (France)	
		Ariu (2016)	8% (Belgium)	
Identifies product firms with service business in their description*	BvD (any)	Neely (2008)	10–60%#	Depends largely on the firm's description. Only extensive margin of servitization
		Sforzi and Boix (2018)	3.4% (Italy) and 5.7% (Spain)	
Identifies product firms with a secondary service sector**	BvD (ORBIS)	Gomes et al. (2018)	3.9% (Spain) and 9.8% (Germany)	Secondary sectors are not compulsory to declare, so it is difficult to build a firm-level control sample. Only extensive margin of servitization. The information is highly reliable when it comes to representing territories.
		Opazo et al. (2018)	n.a.##	
		Sforzi and Boix (2018)	3.6% (Spain)	

Notes:

* Usual keywords for knowledge-based services: research, development, scientific, advertising, design, software, programming, consultancy, streaming, engineering, leasing, usage, creative, intermediation and brokerage.

** Commonly used secondary NAICS codes for knowledge-based services: 518 'Data Processing, Hosting, and Related Services'; 519 'Other Information Services'; 54 'Professional, Scientific, and Technical Services'; 56 'Administrative and Support and Waste Management and Remediation Services'; and 811 'Repair and Maintenance'.

\# The study has a large number of countries.

\## The study does not have a control sample of non-servitized firms.

for 2011, the authors conclude that 5.7% of Spanish manufacturing firms and 3.4% of Italian manufacturing firms are servitized. Gomes et al. (2018) delve more deeply into ORBIS, exploiting the full capacity of the sample by identifying the firms' secondary sector. This method enables identification of firms with manufacturing as the primary industry and knowledge-based services as a secondary industry. In comparing Germany and Spain, Gomes et al.'s (2018) study obtains figures in the same range as Sforzi and Boix (2018). For 2014, they find that 3.89% and 9.79% of product firms are servitized in Spain and Germany, respectively. Conceptually and methodologically, this method seems superior to the others. Our chapter thus aims to estimate current servitization activity for all EU-28 countries with the methodology proposed by Gomes et al. (2018), thereby making an important academic contribution to the literature.

Beyond mapping servitization in Europe, another objective of this study is to depict what inputs drive servitization activities in a given country. We focus on the role of two inputs: manufacturing and digital territorial capabilities. By collecting reliable information on these constructs from the World Bank (manufacturing) and Eurostat (digital exposure), we test three important postulates, two of them bivariate relationships and the third testing multivariate and joint effects.

The first question we attempt to answer is how the manufacturing fabric in a country relates to the percentage of product firms implementing service business models in the same territory. For the case of Spanish autonomous communities, Lafuente, Vaillant and Vendrell-Herrero (2017) identify a virtuous circle of KIBS activity and employment growth in manufacturing sectors. Similarly, for a sample of 121 European regions, Horváth and Rabetino (2018) find that a solid industrial fabric correlates highly with the development of entrepreneurial projects based on the implementation of knowledge-based services. This research stream seems to indicate a positive link between manufacturing and servitization activities at the country level, but this relationship has not yet been explicitly tested. We help to fill this knowledge gap by representing graphically the correlation between these variables and considering the level of economic development as a moderator of this relationship.

Our second goal is to determine whether a direct relationship exists between digitization and servitization activities. Since digital upgrading and smart products are key elements for servitization, these variables are clearly linked at the firm level (Coreynen, Matthyssens and van Bockhaven, 2017; Vendrell-Herrero et al., 2017a). No empirical studies have demonstrated this relationship with a spatial analysis, although the theory of digital dark matter has been proposed (Greenstein and Nagle, 2014; Vendrell-Herrero et al., 2017b). This theory suggests that digitization activity correlates positively with servitization activity at the country level, since more digital infrastructure increases the capacity of businesses and customers in the region to develop more complex business models. We test this suggestion by picturing the digitization–servitization link and considering economic development as a moderating variable. Our final exercise evaluates graphically and through simple regression analysis whether the industrial fabric and digital infrastructure should be seen as substitutes for each other or as complementary.

The following sections provide more details on the data and measurement of the different concepts used, including their geographical mapping. The relationships explained above are then tested. Subsequently, the results and provides various policy recommendations are discussed.

2.2 Mapping servitization across the EU-28: sources, data and variables

To analyse the European geography of servitization activity, as well as this activity's correlation with other country-level variables, we construct a unique database. The data are drawn from multiple sources, including ORBIS (BvD), the World Bank and Eurostat. The sample focuses on the 28-country European Union (including the UK) and collects information for the most recent year available for each variable considered.[1]

As discussed in the previous section and in Table 2.1, there are various ways to compute a country-level measure of servitization activity through secondary databases. We understand the best approach to be that followed by Gomes et al. (2018) and Opazo, Vendrell-Herrero and Bustinza (2018). This approach consists of identifying the percentage of manufacturing firms with a secondary sector in the knowledge-based service sector.[2]

We cleaned the data to ensure comparability between the different countries. After downloading the data from ORBIS for 2017, we identified outliers that required correction. The outliers were three countries with very low values and three countries with extremely high values. The countries at the bottom of the group were Estonia, Malta and Italy, with a percentage of servitized manufacturers of 1% or lower. The countries at the top were Hungary, Slovakia and the Czech Republic, with over 35% servitization,[3] exactly double that of the next-lowest country, Belgium (18%). The figures for all six of these countries were adjusted following the quartile imputation technique (Muñoz and Rueda, 2009). We imputed the average of the bottom quartile (1.97%) to the three countries at the bottom and the average of the top quartile (10.34%) to the three countries at the top.

Figure 2.1 maps the servitization activity in Europe. To simplify the visual analysis, the variable is divided into quartiles. Countries with the highest servitization activity include some of the usual suspects and reflect the apparent concentration of servitization in central Europe. These countries include the Benelux countries, Germany, Hungary Slovakia and the Czech Republic. The top three countries are Belgium (18.5%), Germany (12%) and the Netherlands (11%). The second quartile includes countries with 4.7–9% servitized manufacturers – very rich countries such as Austria (6.5%) and Sweden (5.5%), and relatively poor ones such as Greece (5.5%) and Bulgaria (4.8%). The third

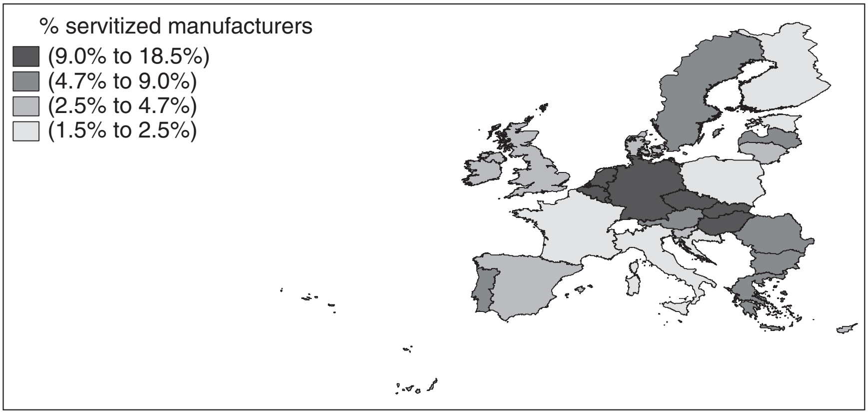

Figure 2.1 Mapping servitization intensity, EU-28.

quartile includes Spain (4.2%), Ireland (3%), the UK (3.1%) and Denmark (3.7%), and the bottom quartile countries like France (2%) and Finland (1.6%).

This study approximates the manufacturing activity of a country as the manufacturing value added as a percentage of GDP. The literature widely accepts this measure as a way to understand the manufacturing strength of an economy (Aquilante, Bustinza and Vendrell-Herrero, 2016; Haraguchi, Cheng and Smeets, 2017). The data were obtained from the World Bank's open data (https://data.worldbank.org/indicator/NV.IND.MANF.ZS) and are from 2016, which is the most recent year available.

Figure 2.2 maps the manufacturing activity in Europe, dividing the data in this figure into quartiles. The manufacturing industry in the countries in the top quartile generates 20–35% of the GDP. Among these countries we find Ireland (35%), the Czech Republic (27%), Hungary (24%) and Germany (23%). The second quartile represents countries with manufacturing value added representing 15–20% of GDP. This category includes countries such as Italy (16%), Finland (17%), Austria (18%) and Poland (20%). Countries with manufacturing value added of 12–15% of GDP compose the third quartile, exemplified by the Netherlands (12%), Spain (14%), Sweden (15%) and Denmark (15%). The bottom quartile contains countries with manufacturing value added of 5–12% of GDP. Surprisingly, countries with a long tradition in manufacturing, such as France (11%) and the UK (10%), are now at the bottom of the classification.

This study computes an economy's level of digitization using the Digital Economy and Society Index (DESI) provided by Eurostat (https://ec.europa.eu/digital-single-market/en/desi). DESI is a composite index that takes values between 0 and 1. It contains information from relevant indicators of country-level digital performance and infrastructure, providing information

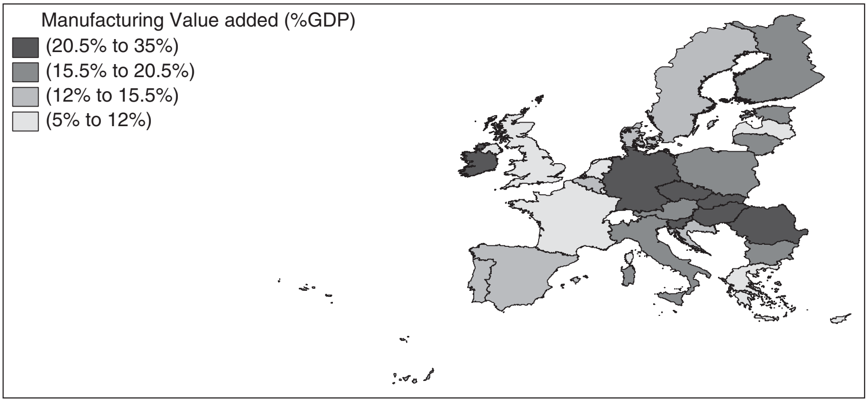

Figure 2.2 Mapping manufacturing intensity, EU-28.

on connectivity, digital skills, the use of internet by citizens and businesses, availability of digitalized public services and development of the ICT sector. This index has been used in previous research that attempts to map the digital capabilities of European countries (Moroz, 2017). Here, we use the DESI for 2017, in which the maximum was 0.67 (Denmark) and the minimum 0.31 (Romania).

Figure 2.3 maps the DESI for the EU-28. The colours of the countries indicate the quartile to which other variables of interest belong. The DESI ranges from 0.56 to 0.67 for the leading group, which includes mostly Scandinavian countries (Sweden, Finland and Denmark lead, with very similar values), the Benelux countries (the Netherlands with 0.64, followed by Belgium with 0.58 and Luxembourg with 0.57) and the UK (0.58). The second quartile (0.51–0.56) is exemplified by German-speaking countries (Germany and Austria both have an index of 0.54) and Ireland (0.55). The third quartile countries, with a DESI of 0.41–0.51, are the Latin countries (Spain and Portugal with an index of 0.51, followed by France with 0.48). With the exception of Italy (0.38), the bottom quartile (0.31–0.41) is composed of EU emerging economies, including Romania (0.31), Bulgaria (0.35) and Poland (0.40).

2.3 Measuring servitization across the EU-28

Our first objective is to disentangle whether manufacturing and servitization are positively correlated, as implied by Lafuente, Vaillant and Vendrell-Herrero (2017), and Horváth and Rabetino (2018). Figure 2.4 shows the possible correlations between these variables for the full sample and three subsamples based on level of income.[4] Our results show a weak (not statistically

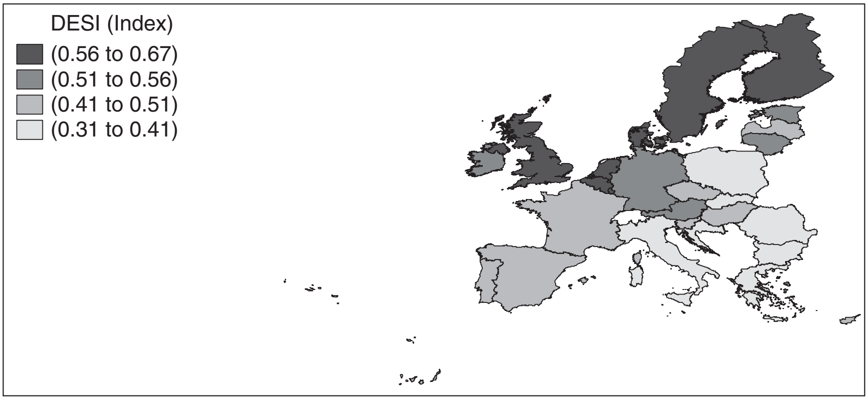

Figure 2.3 Mapping digitization intensity, EU-28.

significant) but positive correlation between servitization and manufacturing (0.091). Interestingly, this correlation is considerably stronger for low- and medium-income groups (0.414 and 0.649, respectively), and even statistically significant at 5% for medium-income groups. However, it is negative for the high-income group (-0.363). Our results thus show that income level moderates the relationship between manufacturing and servitization. Manufacturing drives servitization for relatively poor countries, but has the opposite effect once countries reach a certain income threshold. One explanation for this result is that the richest countries are less dependent on the manufacturing-installed base to deploy service business models. As these countries have more resources, they can obtain manufacturing knowledge from other business ecosystems.

Another consideration is whether digitalization drives servitization (Coreynen, Matthyssens and van Bockhaven, 2017; Greenstein and Nagle, 2014; Vendrell-Herrero et al., 2017b). We analyse this issue in Figure 2.5. The correlation of digitization and servitization is also weak, but slightly higher than that of manufacturing and servitization (0.115 vs. 0.091). In the case of digitization, however, the moderating effect of income groups is practically non-existent. Medium-income groups show essentially no correlation (0.002), and this correlation becomes moderately negative for low- and high-income groups (-0.121 and -0.372, respectively). None of these correlations is statistically significant.

Our bivariate analysis seems to reflect that servitization is not strongly linked to manufacturing and digitization. However, bivariate analysis is limited and introducing more correlates sometimes uncovers new relationships. To better evaluate the relationship between these variables, we undertake multivariate analysis.

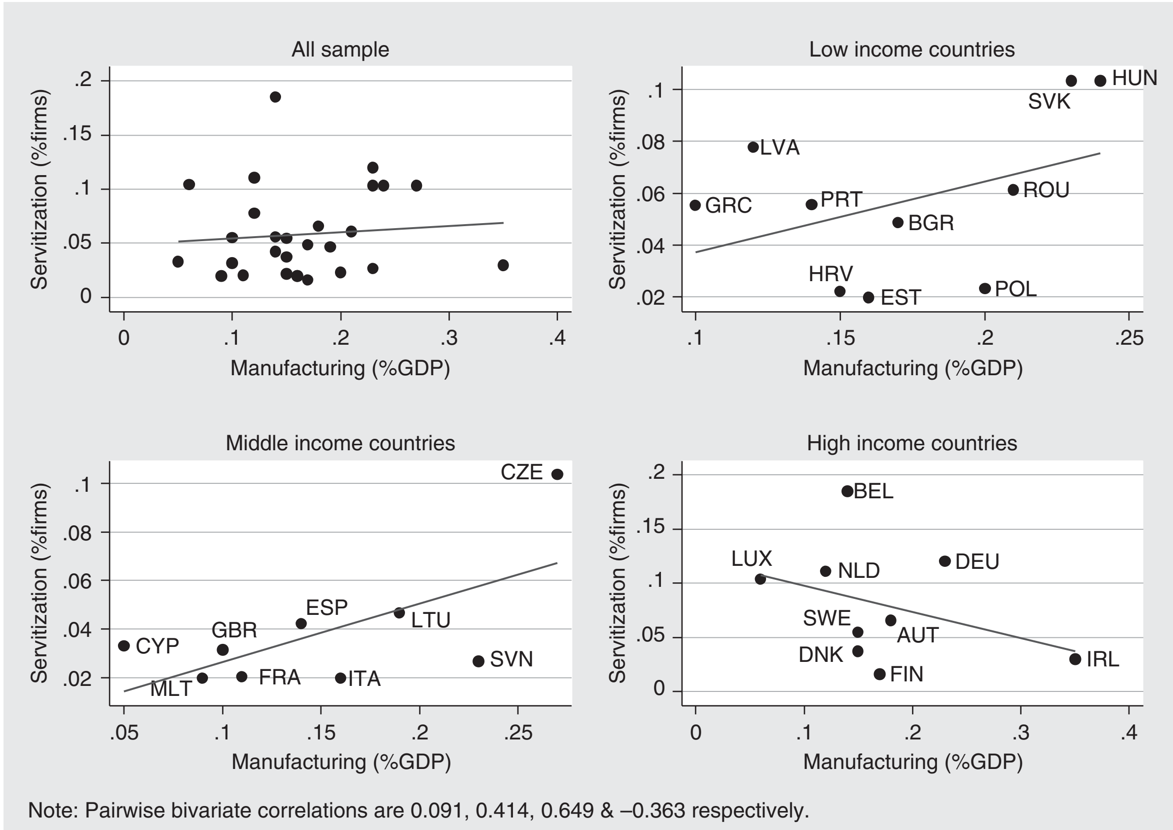

Figure 2.4 Manufacturing and servitization, by income groups.

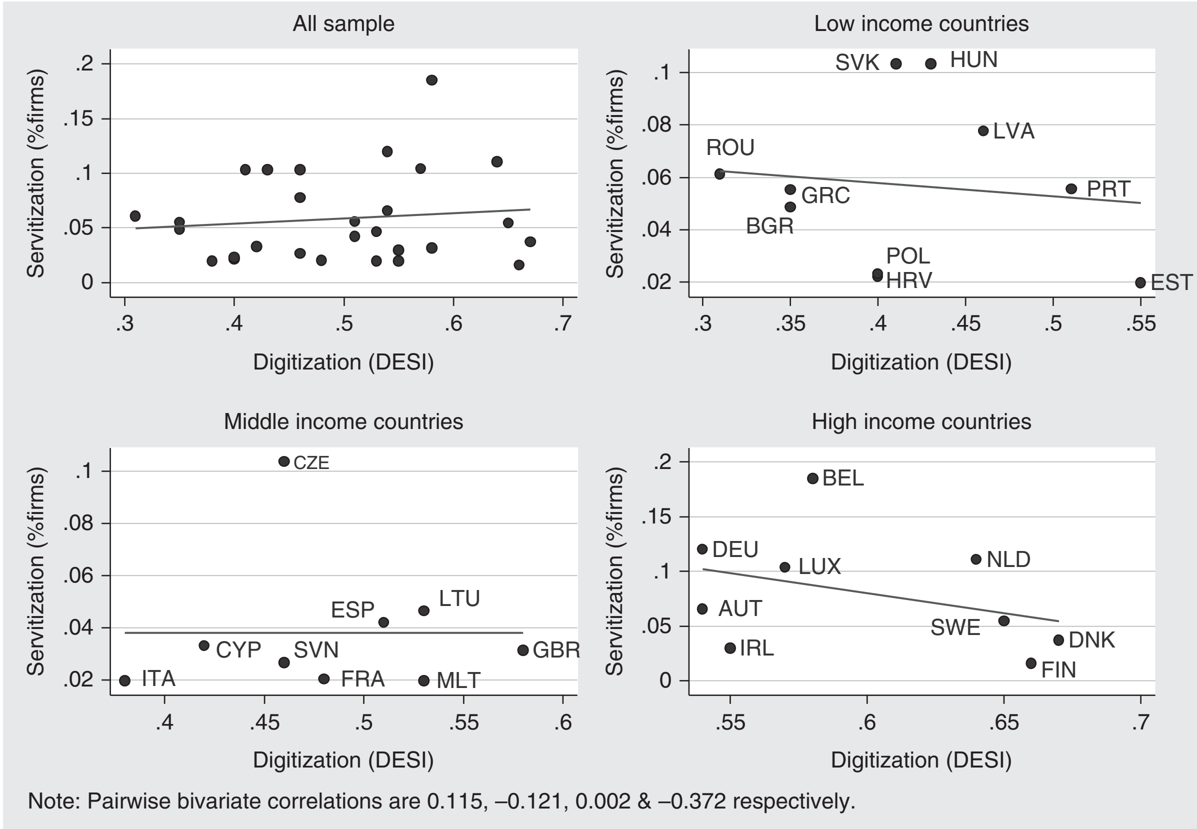

Figure 2.5 Digitization and servitization, by income groups.

The multivariate analysis proposed in this chapter has two phases. First, we attempt to explain graphically how manufacturing, digitization and servitization are interrelated. This analysis already shows some tendencies that require confirmation through statistical inference. In the second phase, we thus undertake regression analysis to confirm/reinforce the results obtained in the initial graphical analysis.

Graphical representation of three variables is complex. One method is to produce a scatter plot of two variables and represent the third by the size (or form or colour) of the marker. Figure 2.6 does precisely this. The horizontal and vertical axes show the DESI values and manufacturing value added as percentages of GDP, respectively. Panel A contains the information on distribution of the 28 EU countries in the scatter plot. One characteristic of this plot is that dotted lines represent the median values of manufacturing and digitization variables, roughly defining four quadrants. Countries positioned in the upper-right quadrant are characterized by relatively high manufacturing and high digitization (e.g., Ireland), whereas countries in the lower-left quadrant are characterized by low manufacturing and low digitization (e.g., Greece). The other quadrants present mixed options; the upper left identifying countries with high manufacturing and low digitization (e.g., Hungary), and the lower right countries with low manufacturing and high digitization (e.g., Belgium).

The size of the circles in Panel B (Figure 2.6) indicates the degree of servitization in the country. It is thus worth examining which quadrant has the largest markers. Theoretically, there are three answers to this question. First, synergetic effects could occur between manufacturing and digitization, making the quadrant with the largest circles the upper right. Secondly, manufacturing and digitization could be seen as substitutes for each other, making the quadrant with the largest circles one of the mixed solutions (upper left or lower right). Thirdly, manufacturing and digitization could exert a negative effect on servitization, making the quadrant with the largest circles the lower left. A visual analysis of Panel B suggests that the quadrants with the largest circles are the mixed solutions. This result implies that manufacturing and digitization are substitutes for each other and that policy makers should focus on stimulating only one of those inputs if the aim is to boost service business models across the industrial fabric. A complementary graphical analysis to show how the three variables are inter-related would use three-dimensional graphs. To this end, Figure 2.7 presents a 3D bar graph in which the lower axes represent a binary measure of manufacturing and digitization variables, and the upper (high) and lower (low) axes the median (Panel A in Figure 2.6). The vertical axis represents the average degree of servitization. This analysis shows even more clearly that mixed (low-high or high-low) combinations boost servitization activity.

As a final exercise, we conduct a regression analysis to validate the results obtained in the graphical analysis (Figures 2.6 and 2.7) through statistical inference. Table 2.2 reports the results of the regression analysis. The dependent

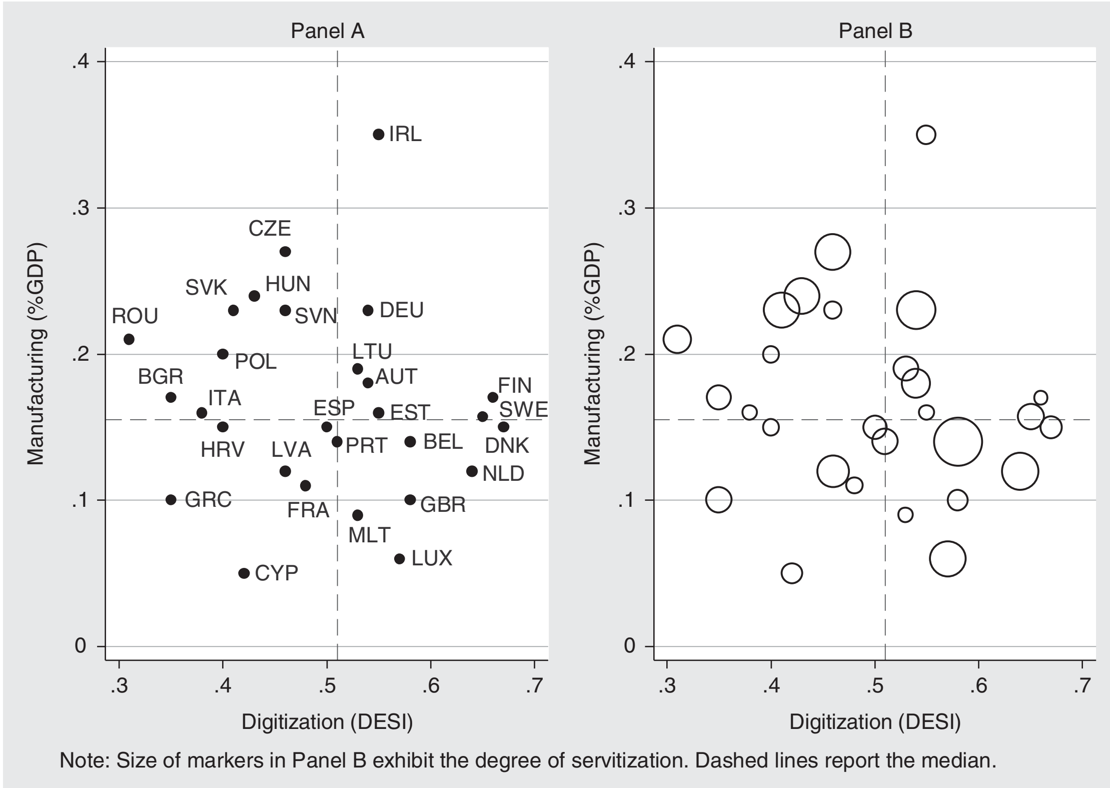

Figure 2.6 Digitization and manufacturing distribution.

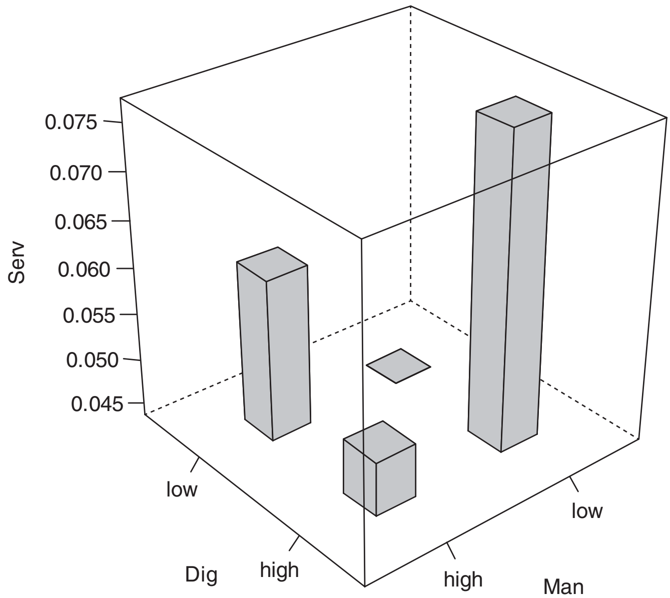

Figure 2.7 The relationship between digitization, manufacturing and servitization.

Table 2.2 Regression analysis

	(1)	*(2)*
[1] DESI	0.479** (0.220)	0.451* (0.228)
[2] Manufacturing (% GDP)	1.395** (0.618)	1.423** (0.603)
[1] * [2]	-2.669** (1.247)	-2.804** (1.179)
Constant	-0.193* (0.108)	-0.177 (0.111)
Income group FE	NO	YES
N	28	28
R^2	0.114	0.159

Notes:
Robust standard errors in parentheses.
Dependent variable: % of manufacturing firms that are servitized.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

variable is servitization, and the independent variables are manufacturing value added as a percentage of GDP, the digitization index (DESI) and the interaction between these two variables. To control for income heterogeneity, we include income group fixed effects in column 2. The model's fit is good, as the R^2 ranges from 11% to 16%.

In both columns, the parameters of manufacturing and digitization are positive and statistically significant (at 5% in most cases). However, the combined effect captured by the interaction term is negative, indicating that increasing both variables (manufacturing and digitization) at the same time has damaging outcomes in terms of the servitization level.

So, the results of the regression analysis confirm that digitization and manufacturing in isolation are positive enablers for servitization, but our results suggest that combining both in the same territory can produce negative consequences in terms of servitization activity. Our graphical and regression analysis suggest that countries with a focus in developing a territorial servitization strategy should specialize in developing manufacturing strength or digital capabilities, but not both at the same time.

2.4 Discussion and conclusions

The implementation of services in the manufacturing industry (servitization) is an increasingly relevant topic. A consolidated academic community currently focuses on how these business models are deployed (Bustinza, Vendrell-Herrero and Baines, 2017) and what drivers and bottlenecks enable and hinder successful implementation of product-service innovation (Bustinza et al., 2018).

The literature also pays increasing attention to the territorial aspects of servitization (Lafuente, Vaillant and Vendrell-Herrero, 2017, 2018). More studies seek to determine how many manufacturers in a territory are servitized. This question is hard to answer because no formal registers are available to catalogue firms deploying these business models and secondary sources are not designed to collect direct information on servitization. Some research examines the data repositories of central banks or fiscal authorities to quantify indirectly the degree of servitization in specific countries (Ariu, 2016; Crozet and Millet, 2017), but this method is usually non-scalable, as it is nearly impossible to access this type of data for more than one country. Other studies use ORBIS (or other BvD data sources) to measure servitization activity (Gomes et al., 2018; Neely, 2008; Opazo, Vendrell-Herrero and Bustinza, 2018; Sforzi and Boix, 2018). Ours is the first research study to provide a cross-country comparison of servitization activity in the EU-28 – a major contribution to the literature.

The cross-country exercise is instructive. We learn that servitization activity seems to be concentrated in Central Europe, particularly in the Benelux countries, Germany, Hungary, Slovakia and the Czech Republic. According to these results, servitization is led by neither the 'old European historical glories' (France, the UK, Spain and Italy) nor the Scandinavian countries. Our study is consistent with current research highlighting the economic emergence of the Visegrád Group (Piotrowicz, 2015; Prokop, Stejskal and Kuvíková, 2017) and the political and economic European leadership of Germany and the Benelux countries (Nurgent, 2017).

A second aim of this study is to identify what causes a country's level of servitization. As we operate with a small sample, our analysis contains three main regressors: income level; the degree of manufacturing; and digitization exposure. As these variables were extracted from very reliable sources, including Eurostat and the World Bank, our findings are relevant for industrial policy.

We find that the countries with the highest servitization specialize in either the industrial fabric or digitization infrastructure and that these inputs of servitization seem to be substitutes for each other. The only country that excels in servitization activity and has high degrees of both manufacturing and digitization exposure is Germany. The other leaders in servitization, such as Belgium and Hungary, specialize in either digitization or manufacturing, respectively.

Our results must be taken with caution. The measure of servitization used has several advantages, but also drawbacks. For instance, legislation governing firms of a certain size whose operations and sales are divided among different sectors is not homogeneous throughout Europe, and our method may produce some outliers. We have made an effort to avoid this problem by cleaning the database of this noise through the quartile imputation method, but the data collected are still subject to bias and criticism. With more homogeneity in future legislation, the method used here will become significantly more reliable. Another limitation of this research is its cross-sectional design. This design is intentional, since the primary aim of this chapter is to produce a preliminary mapping of servitization activity in Europe.

Our goal is to pave the way for future studies of territorial servitization that uncover the geographical composition of servitization inside and outside European boundaries. To this end, we designed a benchmark methodological context as the basis for future longitudinal work, seeking to estimate not only the degree of servitization activity at the country level, but also its rate of growth.

Acknowledgements

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Notes

1 The most recent year is 2017 for servitization and digitization and 2016 for manufacturing value added.
2 Following standard practice (see the bottom of Table 2.1), we used the following secondary NAICS codes to identify knowledge based services: 518 'Data Processing, Hosting, and Related Services'; 519 'Other Information Services'; 54 'Professional, Scientific, and Technical Services'; 56 'Administrative and Support and Waste Management and Remediation Services'; and 811 'Repair and Maintenance'.
3 The best explanation of these values is that declaring secondary industry codes is legally binding in these countries.
4 The income level is obtained by sorting the countries by GDP per capita and clustering them into three groups (high, medium and low) based on their ranking.

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3 Jobs 4.0

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3.1 Introduction

Technology has always driven firms' requirements for skills and knowledge, as well as having changed the nature and content of occupations. This chapter presents cross-country evidence of firms' demand for labour to shed some light on firms' skills requirements, using firms' declared vacancies data from the UK, Italy and Germany. Given the current technological transformation, we want to ascertain what occupations firms are actually seeking to address their medium-term skills needs.

Several studies have shown that the adoption of new technologies (such as computers in the 1980s) was complementary to hiring employees for non-routine jobs, but was a substitute for workers who performed routine jobs, indicating that the demand for different types of jobs is heterogeneous (Autor et al., 2003). In fact, some evidence has documented the correlation between the adoption of computer-based technologies and the increased use of college-educated labour at the industry level. This is referred to as skill-biased technological change, suggesting that technological adoption has destroyed routine jobs (manual and cognitive), whilst increasing less-skilled jobs and high-skilled jobs (Acemoglu, 2002, Autor et al., 2003, Katz and Autor, 1999, Kemeny and Rigby, 2012). So technological change – and in part manufacturing offshoring – resulted in a so-called job polarisation (Autor and Dorn, 2013); that is, the simultaneous increase of employment in the highest- and lowest-skill occupations, as middle-skill occupations disappeared. Job polarisaton of course is linked to a widening wage polarisation and the much-discussed plague of broadening income inequality in advanced economies (OECD, 2019).

The emergence of a wave of new technologies is often referred to as the Fourth Industrial Revolution (FIR) and a fast-growing debate is unpacking its implications for firms, consumers, workers and society more widely. In the chapter, we focus on the impact that in particular automation and digitalisation are expected to have on the labour market and the demand for skills. As suggested above, previous technological shocks were shown to cause significant job losses, especially in the short term, but over the longer term, as the economy adapted to the changes and started to grow again, jobs were eventually created.

So this time round, technological change is also expected to cause labour market adjustments and to trigger medium- and long-term growth and development (see Chapter 1), which in turn will create a new and growing demand for labour, notwithstanding the fact that this demand will be for new jobs or jobs with new and different types of skills and competences (McKinsey Global Institute, 2017).

The purpose of this chapter is to explore firms' demand for skills with vacancies data in the context of a disruptive technological change that has been unfolding for the last couple of years thanks to firms' adoption of FIR technologies. We want to gauge whether firms are anticipating and preparing for the skills requirements of the future by looking at their current demand for labour (i.e. vacancies).

The chapter will proceed as follows. Section 3.2 will briefly present the recent literature on the impact of technological change on the labour market. Section 3.3 will discuss the current debate on the future of work given the spead of FIR technologies. Section 3.4 will present the data and methodology. Section 3.5 will discuss the findings, and a short conclusion will recap the chapter.

3.2 Technological change and job polarisation

3.2.1 Background

Drawing on a large literature on both job polarisation and skill mismatch, we here note a few points to frame the empirical analysis that follows. Technological change and the efficiency-seeking internationalisation strategies of multi-national firms since the 1980s have led to major shifts in labour markets, resulting in job and wage polarisation with evidence primarily from the US (Autor and Dorn, 2013; Autor and Handel, 2013; Boehm, 2014). This has led to overarching concerns with growing intra-country income inequality. Between 1983 and 2007, the growth of low paid jobs was mostly in services and, in particular, personal care jobs (Dwyer, 2013). Other contributions find that job polarisation worsened following the 2008 financial crisis as the subsequent recession was followed by jobless recoveries in the short term (Goos et al., 2014).

Technological change is also argued to trigger imbalances in the labour market between demand and supply in the form of a skill mismatch: this concept captures the degree of heterogeneity in the labour market across a number of dimensions such as skills, industrial sector and location. Significant differences in the skills workers have and those required by firms tend to lengthen the time that it takes to match individuals with jobs. This frictional unemployment is of course a cost to the economy and can cause wide-ranging social difficulties. A skill mismatch can be a short-lived and transitory imbalance in the labour market. More fundamentally, if not addressed, it can lead to structural skill shortages, i.e. linked to megatrends such as digitalisation (Brunello et al., 2019).

In times of rapid technological change, firms face skill challenges not only when hiring but also with their existing labour force. We refer to *'on-the-job' skill mismatch* when workers are either over- or under-skilled for their jobs (vertical on-the-job mismatch) or have different skills/qualifications from those required for the jobs (horizontal on-the-job mismatch) (McGuinness, Pouliaka and Redmond, 2018). This mismatch leads to either redundancy or to the mismatched employees earning less than would otherwise be the case (Bárcena-Martín, Budría and Moro-Egido, 2012). This form of mismatch is dependent on rigidities in the labour market. For example, in a hire-and-fire context, an 'on-the-job' skill mismatch might be limited, but firms pass on to individuals the cost and risk of training and retraining. Conversely, where firms face constraints in terms of firing employees, they might more proactively seek to address the skill mismatch of their labour force with on-the-job training and retraining, and implement a sort of life-long training to ensure that their labour force has the appropriate skills and competences.

Public policy interventions to manage or reduce such skill mismatches are crucial for the long-term growth of an economy and the shared prosperity of its people. This will be discussed at the end of the chapter.

3.3 The skills of the future

Projections, estimations and scenario painting have started to describe what changes in the workplace and labour market the rise of FIR technologies are likely to trigger. To appreciate the scale and pervasiveness of the technological change we are facing, predictions suggest that about two-thirds of children in primary school today are likely to be in occupations that do not yet exist (World Economic Forum, 2018). In the labour market, according to the McKinsey Global Institute (2017), automation and digitalisation will displace up to 30% of the workforce by 2030, especially in advanced economies (namely up to 800 million people) and up to 375 million will switch occupational category by learning new skills. Jobs will be lost primarily in 'physical work in predictable environments and data collection and processing', whilst there will a demand for new skills and especially advanced cognitive capabilities such as logical reasoning and creativity (ibid). With automation and digitalisation also expected to hit high-skill jobs performing routine cognitive tasks, we are again looking at a skill-biased technological change that is likely to result in job polarisation with low-skill and high-skill jobs expected to increase (OECD, 2018). Indeed, technological change is thought to potentially involve jobless growth, making unemployment and under-employment a major business risk globally (De Propris/World Economic Forum, 2016). It has been estimated that 'as many as 45 percent of the activities individuals are paid to perform' are open to automation according to Chui et al. (2015). This conclusion is supported by other studies (Frey and Osborne, 2013; PwC, 2017), though not all envisage such profound effects (e.g. Arntz et al., 2016). It should be noted that automation will affect not just routine and codifiable activities, but also those requiring tacit knowledge and experience (and hence activities where developed countries have a comparative advantage; Rifkin 2014). According to the OECD (2015), around '60% of occupations could have 30% or more of their constituent activities automated'. Such changes would dramatically transform the vast majority of occupations, possibly leading either to jobless growth and/or further job polarisation in the labour markets of developed economies (OECD, 2015).

Changes in the skill content of jobs will become clear relatively quickly, bringing about abrupt job losses in the most affected occupations and affecting some sectors more than others, while job creation will be delayed as individuals grapple with an emerging demand for new skills and seek to acquire them via education and training. This mistiming will create unemployment, which can be frictional or structural depending on the ability and commitment of the education sector, policy makers and businesses to train, retrain or uptrain individuals.

In this disrupted context, education and training are crucial. PwC (2018) explores different labour market scenarios and finds that people feel they are increasingly responsible for their skill development and that access to jobs will depend on people's ability 'to brand and sell their own skills' (PwC, 2014: 19). In other words, in order to respond to changes in the workplace, people are expected to acquire and develop their own skills, adapt to flexible work patterns and environments, and autonomously identify job and career opportunities. Inevitably, this will translate in a *skill divide* that is probably determined from the very early education and training opportunities that individuals might have.

Looking at firms' demand for labour can therefore provide a valuable insight into what occupations they are seeking in the short term and to gauge whether they are already anticipating skills needs that they are missing in their current workforce. We do this with firms' job vacancy data for Italy, Germany and the UK.

3.4 Job vacancy data

3.4.1 German job vacancy data

Vacancy data for Germany was extracted from the Job Vacancy Survey carried out by the Institute for Employment Research (IAB) since 1989 (for more details, see www.iab.de/en/iab-aktuell.aspx). It is the only survey in Germany that measures the development of the unmet labour demand in a representative and statistically robust way. The survey data is subject to strict data protection and confidentiality regulations. This is guaranteed by the Institute for Employment Research as well as the Institute Economic Research & Consulting, which are currently conducting the survey on behalf of the IAB. The population of the main survey in the fourth quarter of every year consists of all firms in Germany with at least one employee subject to social security contributions.

A new stratified random sample is drawn every year from this population. It is stratified by region, seven firm-size classes as well as 23 industries based on the 2008 German classification of industries (NACE rev. 2). This creates a three-dimensional sampling matrix. The dataset covers the entire unfilled labour demand in Germany (structure of vacancies, future labour demand) and identifies the entire number of vacancies in the German labour market (last new hiring and the last case of a failed recruitment effort). Moreover, the survey offers information on lapsed vacancies and on employers' perceptions of recent labour market policy developments, and the special questionnaire examines employers' attitudes and firms' use of current labour market instruments. From this source, we have created a database with information about the number of vacancies in Germany grouped by occupations, regions, firm size and sector classification.

3.4.2 Italy: Excelsior dataset

Job vacancy data in Italy was collected via the Excelsior Information System; since 1997, this has been one of the main Italian sources of information on labour market forecasts. This survey is promoted and produced by Unioncamere (Italian Association of the Chambers of Commerce) with the participation of the Ministry of Labour and the EU (for more details, see https://excelsior.unioncamere.net/eng). It provides detailed and reliable data about the demand for labour by Italian firms both in the short term and in the long term, by region and sector. It also provides information about the specific characteristics of the occupational profiles required by firms, such as age, educational level, type of contract, work experience, difficulty in recruiting specific profiles and need for further training. Moreover, it is aimed at informing policy makers in relation to policies concerning the labour market and the education and training system, ultimately in order to favour the matching between labour supply and demand. The Excelsior survey is included in the official statistics produced on an annual basis within the Italian National Statistical System (SISTAN). The Excelsior Information System is based on data collected through an annual sampled survey conducted on more than 100,000 Italian enterprises (corresponding to about 8% of the total number of Italian companies) operating in the agriculture, manufacturing and service sectors. Firms must be registered with the Business Register and have at least one employee.[1]

3.4.3 The UK: employer skills survey data

The UK Employer Skill Survey is a survey covering approximately 90,000 employers and contains data on vacancies, skills shortages, employee skill gaps and training (for more details, see www.skillssurvey.co.uk/index.htm). It distinguishes between different types of vacancies – e.g. hard-to-fill and skill-shortage vacancies. The data is disaggregated by regions (NUTS 1), vacancy types by occupation (relying on nine Standard Occupational Classification

Major Groups), by broad skill level and by sector disaggregation (13 sectors). Data is also available at the level of Local Enterprise Partnerships and Local Education Authorities. The available vacancy data include:

- number of total vacancies;
- number of hard-to-fill vacancies;
- number of a skills shortage vacancies (prompted or unprompted);
- number of vacancies as a percentage of all employment;
- number of under-utilised staff (i.e. those whose skill levels are above those required in the job they do).

3.5 Methodology

Data is classified using the Eurostat/Isco08 skills classification. We distinguish high-, medium- and low-skill occupations. High-skill occupations include managers, professionals, technicians and associate professionals. Medium-skill occupations include craft and related trades workers, clerical support workers, and skilled agricultural, forestry and fishery workers. Finally, low-skill occupations include elementary occupations, plant and machine operators and assemblers, and service and sales workers. Vacancy data was available only for the following periods: 2011–14 for Germany, 2011–15 for Italy and only the discrete years 2011, 2013 and 2015 for the UK. The unique database we have constructed with firms' job vacancies captures employers' needs and planning in terms of current and near-future skill requirements. In other words, they are telling us what skill they seek on the labour market demand side. Therefore, we can use the job vacancies database as a prediction of firms' skill composition demand at different levels by country.

3.6 Job vacancies trends

We analyse the distribution of vacancies at the national level and the regional level for Germany, Italy and the UK, also considering firms' size and sector. Below we present our findings by country.

3.6.1 Germany

The German data shows that the number of medium-skill vacancies is higher than those of low- and high-skill vacancies, and this is consistent over the period 2011–14. However, the growth rate of vacancies for high- and low-skill jobs is greater than for medium-skill jobs, so over the period firms are seeking to recruit more at the top and bottom ends of the labour market. This suggests a trend towards a possible job polarisation. The positive growth rates of vacancies suggest that in Germany, the labour market is lively and firms are seeking to hire; we cannot say whether they are replacing staff or expanding, but only that they are seeking occupations with specific skills. Consistently, the recovery period in Germany has been characterised by two-thirds of the vacancies being in medium-skill occupations.

Tables 3.1 and 3.2 show the shares of vacancies by skill categories and by firms' size and by region at a more fine-grained level of analysis. In terms of vacancy shares by firm size, small firms (10–49 employees) are seeking medium- and low-skill workers, while medium-sized firms have over the period increasingly focused their recruitment on low- and high-skill jobs. Overall, by 2014, small and medium-sized firms showed the strongest demand for high-skill jobs. The most important results are that the vacancy growth rates are quite high for low- and high-skill occupations for micro-firms (0–9 employees) and medium-sized firms (50–249 employees). The demand for medium- and low-skill workers is negative for large firms (>250 employees) over the period.

3.6.2 Germany's manufacturing sector

What is happening in the German manufacturing sector? In general, growth rates are decreasing and more significantly so for low-skill jobs, even if they are less in demand (see Tables 3.3 and 3.4). Vacancies for medium-skill workers are stable over the period, but these occupations are the most sought-after. Finally, vacancies for high-skill workers suffered mostly in 2013, with a drop of 5,000 in 2012–13, but bounced back in 2013–14.

3.6.3 Germany's business service sector

In the business services sector, only demand for high-skill jobs increased consistently over the entire period and picked up in 2014, whereas the growth rates of vacancies for medium- and low-skill jobs fluctuated with alternating positive and negative growth rates. Overall, the job market seems to be more volatile for low- and medium-skill jobs than for high-skill jobs. This suggests that firms are constantly and increasingly seeking to fill high skill-positions. We cannot tell from the data whether this is related to upskilling or churning strategies (see Tables 3.5 and 3.6).

3.6.4 Italy

In Italy the number of vacancies for medium-skill jobs is significantly higher than in the others two categories, as we saw in the case of Germany. In general, the number of vacancies has fallen over the entire period for all three categories of skills in 2012–13, followed by a slight increase in 2014–15. Stagnation in the job market mirrored a long recession that Italy experienced following the 2008 financial crisis and the austerity policies forced on the country in the following decade. Stagnation meant that those in jobs hung on to their positions, so there was no need to replace them; in addition, firms were not looking to expand and therefore were not hiring. In Italy there is no sign of job polarisation and

Table 3.1 Germany: vacancy shares by firms' size and skills classification, 2011–14

	2011			*2012*			*2013*			*2014*		
	High-skill	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*
1–9 employee	14.4	26.9	16.0	20.2	25.9	27.8	30.5	26.8	16.1	19.6	28.1	27.4
10–49 employee	33.0	34.7	34.4	29.4	42.3	40.5	25.7	34.9	42.6	28.3	37.0	31.7
50–249 employee	25.3	24.8	33.0	19.3	20.6	15.3	21.5	26.4	24.1	27.0	25.1	29.3
>250 employee	27.3	13.6	16.6	31.2	11.2	16.3	22.3	11.8	17.2	25.1	9.8	11.6

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

Table 3.2 Germany: vacancy variation rates by firms' size and skills classification, 2011–14

	2011–2012			*2012–2013*			*2013–2014*			*2011–2014*		
	High-skill	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*
1–9 employee	59.0	-13.4	56.7	69.1	1.6	-19.1	-33.0	20.9	61.6	80.3	6.5	104.8
10–49 employee	1.0	9.5	6.1	-2.1	-18.9	47.1	15.2	22.1	-29.1	13.8	8.5	10.6
50–249 employee	-13.7	-25.5	-58.2	24.9	25.8	119.6	31.2	9.5	15.6	41.5	2.7	6.2
> 250 employee	29.2	-25.6	-11.4	-19.8	3.2	46.7	17.3	-4.5	-35.5	21.5	-26.7	-16.2
Total	13.4	-10.1	-9.9	11.9	-1.9	39.7	4.4	15.3	-4.8	32.5	1.7	19.8

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

Table 3.3 Germany: absolute values of vacancies by skills classification in the manufacturing sector, 2011–14

	2011	*2012*	*2013*	*2014*
High-skill	20,591	19,938	14,549	19,982
Medium-skill	46,653	49,136	45,794	45,884
Low-skill	7,124	8,261	7,252	5,871
Total	74,368	77,335	67,595	71,737

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

Table 3.4 Germany: vacancy variation rates by skills classification in the manufacturing sector, 2011–14

	2011–2012	*2012–2013*	*2013–2014*	*2011–2014*
High-skill	-3.2	-27.0	37.3	-3.0
Medium-skill	5.3	-6.8	0.2	-1.6
Low-skill	16.0	-12.2	-19.0	-17.6
Total	4.0	-12.6	6.1	-3.5

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

Table 3.5 Germany: absolute values of vacancies by skills classification in the business service sector, 2011–14

	2011	*2012*	*2013*	*2014*
High-skill	87,836	99,205	100,977	115,848
Medium-skill	316,952	259,945	257,079	299,894
Low-skill	92,076	73,204	92,102	86,440
Total	496,864	432,354	450,158	502,182

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

Table 3.6 Germany: vacancy variation rates by skills classification in the business service sector, 2011–14

	2011–2012	*2012–2013*	*2013–2014*	*2011–2014*
High-skill	12.9	1.8	14.7	31.9
Medium-skill	-18.0	-1.1	16.7	-5.4
Low-skill	-20.5	25.8	-6.1	-6.1
Total	-13.0	4.1	11.6	1.1

Source: Authors' elaboration based on IAB Job Vacancy Survey Data.

as the demand for labour improved from 2014, all skill profiles were sought, but medium-skill jobs still accounted for two-thirds of all vacancies.

In Italy micro-enterprises (1–9 employees) show the greatest demand for medium- and low-skill labour, whereas large firms seem to seek to hire high-skill labour. Medium-sized firms are less active in the labour market across all levels of skills (see Table 3.7). In general, all the enterprises suffered during the recession years, as negative variation rates between 2011 and 2013 show in Table 3.8; firms started hiring again in 2014 when the first positive signs of growth started to appear. All firms sustained the labour market until 2015; however, whilst large firms sought high- and mid-skill labour, micro-firms and small firms were seeking low- and medium-skill profiles. This can be particularly worrying as the adoption of new FIR technologies requires firms to upskill their labour force and some of this upskilling involves high-skill occupations. Italy's industrial structure is chartered by small firms and their ability to retain and retrain their human capital will be a precondition for their survival.

3.6.5 Italy's manufacturing sector

An overview of vacancies in the manufacturing sector reflects a weak demand for labour across all skill levels and a slight recovery in 2015 (see Table 3.9), and growth rates turning positive only in 2014–15, especially for low-skill and high-skill profiles (see Table 3.10). Again, the data suggests a lack of job polarisation in Italy, but growth trends suggest an increasing acceleration of vacancies for low-skill and high-skill profiles.

3.6.6 Italy's business service sector

In the business services sector, the data shows similar patterns, with vacancies picking up after 2014 across all levels of skills. Half of the vacancies are in medium-skill occupations, although low-skill and high-skill profiles are growing faster than medium-skill profiles.

3.6.7 The UK

In the UK, the number of vacancies seems to be greater for high- and low-skill jobs, which is different from what we found in Germany and Italy. In general, the number of vacancies grew steadily between 2011 and 2015, suggesting that firms were seeking to hire, although as we can see in Table 3.13, mostly in low-skill and medium-skill occupations. We find that in the UK, the most active firms were the micro-enterprises (0–24 employees – note that the UK firm size classification is different from that in Germany and Italy) in 2011, with the greatest vacancy shares, around 60% for medium- and low-skill jobs; however, by 2015, medium (100–249 employee) and large (>250 employees) firms large accounted for about 50% of high-skill vacancies, and small firms (25–99 employees) accounted for 40% of low-skill vacancies (see Table 3.13).

Table 3.7 Italy: vacancy shares by firms' size and skills classification, 2011–15

	High-skill	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*
1–9 employees	30.4	46.7	32.2	27.9	44.7	33.9	27.9	44.2	29.2	25.7	42.1	30.2	23.8	41.6	32.5
10–49 employees	21.8	21.5	26.4	17.5	19.2	23.6	20.4	22.0	24.8	18.9	23.5	24.2	18.0	22.5	24.2
50–249 employees	18.4	10.8	18.5	19.8	10.5	17.4	19.0	10.6	18.1	19.3	10.8	18.5	20.2	9.9	16.6
250 and more employees	29.4	21.0	22.9	34.8	25.5	25.1	32.6	23.2	27.9	36.1	23.5	27.1	38.0	25.9	26.7

Source: Authors' elaboration based on Excelsior Data.

Table 3.8 Italy: vacancy variation rates by firms' size and skills classification, 2011–15

	High-skill	*Medium skill*	*Low-skill*	*High-skill*	*Medium skill*	*Low-skill*	*High-skill*	*Medium skill*	*Low-skill*	*High-skill*	*Medium skill*	*Low-skill*	*High-skill*	*Medium skill*	*Low-skill*
1–9 employees	–39.3	–26.3	–21.1	–1.2	–10.8	–30.1	–5.0	4.6	14.3	13.0	13.8	30.9	–35.6	–21.7	–17.6
10–49 employees	–46.6	–30.9	–33.0	14.7	3.4	–15.0	–4.3	17.2	8.3	16.3	10.2	21.4	–31.8	–7.7	–25.2
50–249 employees	–28.7	–24.9	–29.9	–5.4	–9.1	–15.6	4.9	12.2	13.1	27.7	5.5	9.0	–9.6	–19.2	–27.0
250 and more employees	–21.6	–6.4	–17.8	–7.5	–18.1	–9.9	14.1	11.6	7.4	28.4	26.5	19.5	6.3	8.2	–4.9
Total	–33.7	–22.9	–25.1	–1.4	–9.8	–19.0	3.2	9.8	10.7	22.0	15.0	21.5	–17.7	–12.1	–18.4

Source: Authors' elaboration based on Excelsior Data.

Table 3.9 Italy: absolute value of vacancies by skills classification in the manufacturing sector, 2011–15

	2011	*2012*	*2013*	*2014*	*2015*
High-skill	32,815	24,643	23,370	22,613	31,568
Medium-skill	70,454	53,312	46,568	50,227	58,348
Low-skill	66,475	45,073	35,581	42,155	72,642
Total	169,744	123,028	105,519	114,995	162,558

Source: Authors' elaboration based on Excelsior Data

Table 3.10 Italy: vacancy variation rates by skills classification in the manufacturing sector, 2011–15

	2012/2011	*2013/2012*	*2014/2013*	*2015/2014*	*2015/2011*
High-skill	-24.9	-5.2	-3.2	39.6	-3.8
Medium-skill	-24.3	-12.7	7.9	16.2	-17.2
Low-skill	-32.2	-21.1	18.5	72.3	9.3
Total	-27.5	-14.2	9.0	41.4	-4.2

Source: Authors' elaboration based on Excelsior Data.

Table 3.11 Italy: absolute value of vacancies by skills classification in the business service sector, 2011–15

	2011	*2012*	*2013*	*2014*	*2015*
High-skill	108,138	72,402	70,638	72,428	93,213
Medium-skill	258,331	194,054	167,559	182,045	215,309
Low-skill	169,300	111,645	91,216	102,358	132,223
Total	535,769	378,101	329,413	356,831	440,745

Source: Authors' elaboration based on Excelsior Data.

Table 3.12 Italy: vacancy variation rates by skills classification in the business service sector, 2011–15

	2011–2012	*2012–2013*	*2013–2014*	*2014–2015*	*2011–2015*
High-skill	-33.0	-2.4	2.5	28.7	-13.8
Medium-skill	-24.9	-13.7	8.6	18.3	-16.7
Low-skill	-34.1	-18.3	12.2	29.2	-21.9
Total	-29.4	-12.9	8.3	23.5	-17.7

Source: Authors' elaboration based on Excelsior Data.

Table 3.13 The UK: vacancy shares by firms' size and skills classification, 2011, 2013 and 2015

	2011			*2013*			*2015*		
	High-skill	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*
1–24 employees	44.3	61.5	60.0	38.5	52.4	46.6	17.5	29.1	22.5
25–99 employees	22.2	18.1	20.1	24.6	19.0	27.7	28.9	34.3	39.7
100–249 employees	13.5	9.8	9.8	15.6	10.9	14.5	26.8	17.7	27.8
250 and more employees	20.0	10.7	10.2	21.3	17.7	11.1	26.9	18.9	10.0

Source: Authors' elaboration based on Employer Skills Survey Data.

Table 3.14 The UK: vacancy variation rates by firm sizes' and skills classification, 2011, 2013 and 2015

	2013/2011			*2015/2013*			*2015/2011*		
	High-skill	*Medium-skill*	*Low-skill*	*High-skill*	*Mid Skill*	*Low-skill*	*High-skill*	*Medium-skill*	*Low-skill*
1–24 employees	–10.4	–13.4	1.7	–41.0	–17.0	–25.6	–47.1	–28.1	–24.3
25–99 employees	14.1	6.5	80.7	53.4	170.4	120.5	75.0	188.1	298.4
100–249 employees	18.7	13.2	93.8	124.3	143.5	195.0	166.3	175.7	471.8
250 and more employees	10.1	68.3	43.1	64.0	59.9	38.8	80.5	169.2	98.7
Total	3.1	1.5	30.8	30.3	49.7	54.1	34.3	52.0	101.6

Source: Authors' elaboration based on Employer Skills Survey Data.

The variation rates are always positive and high over the period: this suggests that the situation of the job market is quite different in the UK from the other two countries (Table 3.14). Overall, there is a high job mobility market, and the high number of vacancies suggests that workers are moving from one job to another one quite easily.

Growing vacancy rates might be explained in many ways: it might be that firms are replacing mobile talent, expanding the existing labour force or seeking complementary skills. The data cannot tell us anything about this; however, we

Table 3.15 The UK: absolute value of vacancies by skills classification in the manufacturing sector, 2011, 2013 and 2015

	2011	*2013*	*2015*
High-skill	12,203	11,916	13,260
Medium-skill	12,981	10,775	15,328
Low-skill	12,727	11,684	19,209
Total	37,848	34,375	47,797

Source: Authors' elaboration based on Employer Skills Survey Data.

Table 3.16 The UK: vacancy variation rates by skills classification in the manufacturing sector, 2011, 2013 and 2015

	2013/2011	*2015/2013*	*2015/2011*
High-skill	-2.4	11.3	8.7
Medium-skill	-16.6	42.3	18.7
Low-skill	-8.2	64.4	50.9
Total	-9.2	39.0	26.3

Source: Authors' elaboration based on Employer Skills Survey Data.

find large vacancy growth rates for small, medium and large-sized firms from 2011 to 2015 for medium and low skills, whereas large firms are mainly looking for high-skill workers. Meanwhile, micro-firms show signs of withdrawing from the labour market.

3.6.8 The UK's manufacturing sector

In the case of the manufacturing sector, there is no clear evidence of job polarisation in the jobs firms try to fill: in 2011, vacancies were evenly distributed across the different skill categories, while in 2015, the highest demand was for low-skill workers, followed by the medium-skill workers.

In particular, in the manufacturing sector vacancies contracted between 2011 and 2013 (post-crisis), but picked up again in 2013, signalling a dynamism in the sector which was mostly export-driven. Worryingly, however, the vacancies that grew the most were for low- and medium-skill workers.

3.6.9 The UK's business services sector

In the business services sector there appears to be some evidence of job polarisation in 2011 and 2013, while in 2015 vacancies for low-skill and medium-skill workers grew the fastest. In this sector, the data shows an increase of 200,000 vacancies between 2013 and 2015 (see Table 3.17).

Table 3.17 The UK: absolute value of vacancies by skills classification in the business service sector, 2011, 2013 and 2015

	2011	*2013*	*2015*
High-skill	143,099	140,818	182,390
Medium-skill	72,986	71,925	114,218
Low-skill	148,587	150,804	239,918
Total	364,672	363,547	536,526

Source: Authors' elaboration based on Employer Skills Survey Data.

Table 3.18 The UK: vacancy variation rates by skills classification in the business service sector, 2011, 2013 and 2015

	2013/2011	*2015/2013*	*2015/2011*
High-skill	-1.6	29.5	27.5
Medium-skill	-1.5	58.8	56.5
Low-skill	1.5	59.1	61.5
Total	-0.3	47.6	47.1

Source: Authors' elaboration based on Employer Skills Survey Data.

The service sector has very big variation rates in terms of vacancies for all three kinds of workers between 2015 and 2013 and between 2015 and 2011. However, between 2011 and 2013 (post-crisis), the situation appeared quite stationary.

3.7 Conclusions

The novel contribution of this chapter is to explore job vacancies in Germany, Italy and the UK. We used regional, sectoral and firm size data to reveal firms' demand for skills. Our analysis suggests that German and British firms were very active in looking for labour, notably in terms of high-skill labour in Germany and low-skill labour in the UK. Meanwhile, in Italy there was evidence of a stagnant job market where the demand for medium-skill workers was the largest. Finally, it is perhaps surprising that the sectoral analysis suggests that the service sector seems more receptive to Industry 4.0 skills than the manufacturing sector. Job vacancies data provides valuable information on firms' skill needs; however, unfortunately it does not enrich the analysis with details about the why and how of labour market changes. Nevertheless, we feel that a number of policy recommendations can be drawn from our research:

1 There is a need to raise awareness at the firm level of the types of skills needed to adopt new technologies. The extent to which firms still demand low-skill jobs raises some concerns with respect to their possible lack of readiness to fully exploit the benefits of all the FIR technologies. This

means that key stakeholders have a role to play in informing, alerting and advising firms on what skills they need, given the sectors they operate in and the activities they are undertaking. Such skills may be in the local labour market or may need to be acquired via the existing workforce.

2 The education system needs to start updating its programmes to include competences related to FIR technologies in order to avoid structural skill mismatches in the labour market.

3 The fast pace of technological change means that firms will experience rapid skill obsolescence. A solution would be for firms to prioritise constant on-the-job reskilling and upskilling of their internal labour force by accessing general or tailored courses offered by specialist providers, especially for smaller firms who might not have the in-house facilities and scale to invest in competence building.

4 Industry associations and public sector stakeholders can work with the knowledge-intensive business sector by supporting the latter to emerge and develop symbiotically with the industrial specialisation of the regional economy in order to offer tailored, customised and bespoke training programmes.

5 Skills formation is often considered a good example of market failure necessitating government intervention in order to compensate for the private sector's under-investment due to free-riding concerns. However, skills formation will increasingly become a multi-dimensional requirement for firms, government and society. The lack of skills will impact on people's employability and therefore on their job prospects and income. At the same time, governments will need up-to-date skills and competences across their range of departments in order to understand the policy and regulatory implications of technological change. Furthermore, firms can only become or remain competitive if their physical investments in digitally enabled technologies are dovetailed with investment in competence building. This means that skills formation cannot be left solely to schools and universities; firms need to be compelled to proactively invest and plan for the skills they need and will need. Policy needs in turn to incentivise firms to retain and retrain its labour force by introducing, for instance, 'skills vouchers' (similar to innovation vouchers) or programmes such as industrial doctorate programmes or apprenticeships.

Note

1 Public administration, public enterprises in the health sector, public primary and secondary schools, public universities and other no-profit organisations are excluded.

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